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STUDIES ON VIM OAT FEED. 2. THE DIGESTIBILITY OF OAT HULLS

C. J. WATSON[1], G. W. MUIR[2] and W. M. DAVIDSON[3]

Central Experimental Farm, Ottawa, Ont.

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Under the Feeding Stuffs Act of Canada (*1*) six grades are provided for oat products, namely, Oat Groats, Oat Hulls, Oat Middlings, Oat Shorts, Clipped Oat By-product and Oat Feed.

Oat Hulls and Oat Feed are defined, respectively, as follows:

"Oat Hulls are the outer covering of the oat, and any by-products obtained in the milling of rolled oats from clean oats, and containing 28 per cent or more of fibre, shall be designated as 'oat hulls'."

"Oat Feed consists of offal obtained in the milling of rolled oats from clean oats, and containing less than 28 per cent of fibre. It must include not less than the mill-run of oat middlings and not more than the mill-run of oat hulls".

The object of the present investigation is to compare the feeding values of representatives of each of these two grades upon the basis of digestibility trials.

The digestibility of Vim Oat Feed, together with an estimate of its feeding value based upon this digestibility, was published in a previous communication (*5*). In order to make a comparison between the value of oat hulls and the value of Vim Oat Feed, it was necessary to repeat with oat hulls essentially the same procedure that had been adopted in the case of the Vim Oat Feed.

The feeds used differed in physical make-up. The Vim Oat Feed was purchased in the form of finely ground meal while the oat hulls, though put through a hammer mill, were much coarser. In fact, it was not found possible to duplicate, in the oat hulls, the condition of the Oat Feed and the former still contained a large proportion of small, broken hull particles. The comparison in value, therefore, was made between finely ground Vim Oat Feed and coarsely ground oat hulls. The composition of the feeding stuffs used is given in Appendix Table 11.

Four grade Shorthorn steers were used in the experiments, with an initial weight averaging 1010 pounds and a final weight averaging 1181 pounds. Their age at the commencement of the trials was a few months over two years. The trials began in August, 1932, and were concluded in June, 1933. The steers were numbered 84387J, 84381J, 84424J and 84422J.

[1] Chemist, Division of Chemistry.
[2] Dominion Animal Husbandman.
[3] Assistant in Chemistry.

The digestion trials consisted of a fourteen-day preliminary period followed by a collection period of twelve days. The collection period was divided into three sub-periods during each of which the feed and excrement were composited, sampled and analyzed. The daily ration was fed in two equal quantities at 5.30 a.m. and 4.30 p.m. The animals were watered by hand one hour after each feeding.

The digestion trials were conducted in the following order:

(1) Experiment AN 13–1: Digestibility of a basal ration of mixed clover and grass hay.

(2) Experiment AN 13–2: Digestibility of a mixed ration of the above hay ration and oat hulls.

(3) Experiment AN 13–3: Digestibility of oat hulls, fed alone.

(4) Experiment AN 13–4: Digestibility of a basal ration of mixed clover and grass hay.

(5) Experiment AN 13–5: Digestibility of a mixed ration of the above hay and oat hulls.

(6) Experiment AN 7–2: Digestibility of Vim Oat Feed fed alone.

All the necessary data pertaining to the digestion trials are given in Tables 11 to 17 in the appendix. A summary of the coefficients of digestibility is given in Tables 1 to 6 which follow.

TABLE 1.—COEFFICIENTS OF DIGESTIBILITY OF THE BASAL RATION OF CLOVER AND MIXED HAY. DAILY RATION—7.5 KILOS

	Experiment AN 13–1					Experiment AN 13–4		
	Animal 84387J	Animal 84381J	Animal 84424J	Animal 84422J	Average	Animal 84387J	Animal 84381J	Average
Dry matter	59.8	59.4	59.6	59.7	59.6	59.7	59.1	59.4
Organic matter	63.0	62.9	63.1	63.6	63.2	61.1	60.5	60.8
Nitrogen	59.4	61.2	58.8	61.2	60.2	62.3	63.4	62.9
Ether extract	29.9	23.3	29.4	22.8	26.4	41.6	41.8	41.7
Crude fibre	57.0	57.2	56.2	60.0	57.6	54.4	52.9	53.7
N-free extract	68.8	68.5	69.5	68.3	68.8	65.8	65.6	65.7

TABLE 2.—COEFFICIENTS OF DIGESTIBILITY OF MIXED RATION OF HAY AND OAT HULLS

	Experiment AN 13–2				Experiment AN 13–5		
	Hay —5.5 kg. Hulls—2.5 kg.		Hay —5.5 kg. Hulls—5.0 kg.		Hay —5.5 kilos Oat Hulls—2.5 kilos		
	Animal 84387J	Animal 84381J	Animal 84424J	Animal 84422J	Animal 84387J	Animal 84381J	Animal 84424J
Dry matter	52.4	49.2	43.7	44.2	49.9	47.4	47.3
Organic matter	55.2	51.8	46.7	46.8	51.2	49.0	49.1
Nitrogen	54.6	53.8	49.1	51.4	58.4	57.9	56.0
Ether extract	34.0	38.5	35.4	30.3	44.3	35.3	37.4
Crude fibre	53.6	47.3	44.3	45.1	47.0	45.1	44.7
N-free extract	56.6	54.4	48.0	47.8	52.5	50.4	51.0

TABLE 3.—CALCULATED COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS

——	Calculated from Experiment AN 13–2				Calculated from Experiment AN 13–5			Mean	Co-efficient of variation	Standard Error
	Animal 84387J	Animal 84381J	Animal 84424J	Animal 84422J	Animal 84387J	Animal 84381J	Animal 84424J			
Dry matter	36.6	26.4	26.5	27.5	29.1	21.1	20.8	26.9	19.8	±2.02
Organic matter	38.4	27.7	29.4	29.6	30.4	23.6	23.9	29.0	17.1	±1.88
Nitrogen	—	—	—	—	—	—	—	—	—	—
Ether extract	—	—	75.5	47.9	—	—	—	—	—	—
Crude fibre	46.3	28.4	32.2	33.7	34.2	28.6	27.7	33.0	19.2	±2.43
N-free extract	33.8	27.4	28.5	28.2	28.0	21.7	23.5	27.3	14.2	±1.47

TABLE 4.—CALCULATED COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS OMITTING ANIMAL NO. 84387J

——	Mean	Coefficient of variation	Standard Error
Dry matter	24.5	13.2	±1.45
Organic matter	26.8	10.9	±1.30
Nitrogen	—	—	—
Ether extract	—	—	—
Crude fibre	30.1	8.8	±1.19
N-free extract	25.8	11.9	±1.37

In regard to Tables 3 and 4, animal 84387J showed a peculiar idiosyncrasy in the digestion trials of this investigation as well as in other investigations conducted during the year. The coefficients of digestibility of any given single feed when determined with this animal always agreed closely with those determined on the other animals. In the case of the mixed rations, however, the coefficients of digestibility as determined with animal 84387J were always much higher than those of the others. This increase corresponded with an increase in the digestibility of the crude fibre and may indicate a more active fermentation in the digestive tract. Accordingly, for comparison with Vim Oat Feed, all calculations have been made both including and excluding the results of animal 84387J.

TABLE 5.—COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS WHEN FED AS THE SOLE FEED IN A RATION. DAILY RATION—7.5 KILOS

——	Animal 84387J	Animal 84381J	Animal 84424J	Animal 84422J	Mean	Co-efficient of variation	Standard Error of mean
Dry matter	39.2	38.7	40.8	42.3	40.3	4.06	±0.82
Organic matter	41.5	40.5	42.5	44.4	42.2	3.95	±0.83
Ether extract	44.2	51.6	49.2	41.0	46.5	10.30	±2.40
Crude fibre	50.8	48.7	51.4	51.9	50.7	2.77	±0.70
N-free extract	37.1	36.1	38.3	40.8	38.1	5.32	±1.01

In Table 6, to the results obtained in this investigation when Vim Oat Feed was fed alone, have been added the results obtained in a similar manner during the previous year's work (*5*).

TABLE 6.—COEFFICIENTS OF DIGESTIBILITY OF VIM OAT FEED WHEN FED AS THE SOLE FEED IN A RATION

——	1932		1933		Mean	Co-efficient of variation	Standard Error of mean
	Experiment AN 7–1		Experiment AN 7–2				
	Animal 84387J	Animal 84381J	Animal 84424J	Animal 84422J			
Dry matter	33.5	33.5	37.5	38.9	35.9	7.73	±1.39
Organic matter	34.5	35.2	39.6	41.0	37.6	8.54	±1.61
Nitrogen	45.7	40.3	50.5	53.6	47.5	12.23	±2.91
Ether extract	66.3	66.9	74.5	71.4	69.8	5.57	±1.94
Crude fibre	32.7	33.5	36.2	36.6	34.8	5.58	±0.97
N-free extract	33.2	34.3	38.6	40.8	36.7	9.75	±1.79

COMPARISON OF THE DIGESTIBILITY OF OAT HULLS WITH THAT OF VIM OAT FEED

The results given in Tables 3, 4, 5 and 6 are summarized in Tables 7 and 8. The values for Vim Oat Feed given in Table 7 were taken from the previous publication (*5*).

From an examination of Table 7, it will be seen that the coefficients of digestibility of the dry matter and the organic matter were similar for both the oat hulls and the Vim Oat Feed. The digestibility of the crude fibre of the hulls was significantly[4] greater than that of the Vim Oat Feed, while the digestibility of the nitrogen-free extract tended to be lower. Figures for the digestibility of the nitrogen are not included since it was not possible to determine these values for the oat hulls. The coefficient

TABLE 7.—COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS AND VIM OAT FEED CALCULATED FROM A MIXTURE OF EACH WITH HAY

——		Dry matter	Organic matter	Crude fibre	Nitrogen-Free extract
Vim Oat Feed	Mean (four values)	25.7	27.0	18.4	30.0
	Coefficient of variation	8.45	8.19	13.70	7.21
	Standard Error of mean	±1.09	±1.11	±1.26	±1.08
Oat Hulls, including animal 84387J	Mean (seven values)	26.9	29.0	33.0	27.3
	Coefficient of variation	19.8	17.1	19.5	14.2
	Standard Error of mean	±2.02	±1.88	±2.43	±1.47
Oat Hulls, omitting animal 84387J	Mean (five values)	24.5	26.8	30.1	25.8
	Coefficient of variation	13.2	10.9	8.8	11.9
	Standard Error of mean	±1.45	±1.30	±1.19	±1.37

[4] "Significance of differences of mean of small samples" from Fisher's "Statistical Methods for Research Workers", page 109 (1925), was used to determine the significance of the differences in this publication.

of digestibility of the nitrogen for Vim Oat Feed had been found previously to be 52%.

In spite of the difference in digestibility of the crude fibre contents of the two feeds, there was no difference in the digestibility of the dry matter contents. This was due to the summation of two factors, the mathematical difference in the digestibility of the nitrogen-free extract added to the small amount of digestible protein in Vim Oat Feed.

As an explanation for the reciprocal condition existing in the case of the coefficients of digestibility of crude fibre and nitrogen-free extract, two reasons may be advanced. In the first place, some material determined as "crude fibre" in the analysis of a feed may, in the analysis of the feces be removed by the acid-alkali treatment and reported as "nitrogen-free extract".[5] The quantity of such material may have been greater in the case of the oat hulls than with the Vim Oat Feed. In the second place, the oat hulls, owing to their more bulky condition may have been retained for a greater length of time in the reticulo-rumen cavities. Under this circumstance, they would be subjected to a greater fermentation which may have influenced the digestibility of the crude fibre.

From an examination of Table 8, it will be seen that the relationship of the digestibility of the oat hulls to the Vim Oat Feed when each was fed as the sole ration was qualitatively the same as that when each had been fed in a mixed ration with hay. The coefficient of digestibility of the

TABLE 8.—COEFFICIENTS OF DIGESTIBILITY OF VIM OAT FEED AND OAT HULLS WHEN FED ALONE

		Dry matter	Organic matter	Crude fibre	Nitrogen-free extract
Vim Oat Feed	Mean (four values)	35.9	37.6	34.8	36.7
	Coefficient of variation	7.73	8.54	5.58	9.75
	Standard Error of mean	±1.39	±1.61	±0.97	±1.79
Oat hulls	Mean (four values)	40.3	42.2	50.7	38.1
	Coefficient of variation	4.06	3.95	2.77	5.32
	Standard Error of mean	±0.82	±0.83	±0.70	±1.01

crude fibre of the oat hulls as before was significantly higher than that of the Vim Oat Feed. The differences between the digestibilities of the organic matter and the nitrogen-free extract, respectively, for the two feeds were, on the other hand, not significant. In the case of the dry matter, the odds are about 20 to 1, that the difference is significant.

It will be noticed in Table 8 that the coefficients of variation are larger for the results with the Vim Oat Feed than with the oat hulls. These values for the Vim Oat Feed were obtained from different shipments in different seasons and different experiments. The values for the oat hulls, on the other hand were determined with one shipment and in one experiment only. The values obtained for Vim Oat Feed with animals 84424J and 84422J (see Table 6) correspond to the values obtained with the oat hulls in point of shipment and time of experiment. They also

[5] This same viewpoint has been expressed by Mitchell in a recent publication (*2*).

closely approach those for oat hulls in magnitude with the exception of the crude fibre, the digestibility of which is still considerably lower for the Vim Oat Feed than for the oat hulls.

Comparison of Oat Hulls and Vim Oat Feed on the Basis of Their Content in Digestible Nutrients

In Table 9, a comparison is made between the contents of digestible nutrients in oat hulls and in Vim Oat Feed, the results being calculated to the moisture-free basis. The values given are averages of calculations made on each individual digestion trial. In the case of oat hulls, the deviations are the result not only of the variations in the coefficients of digestibility but also of the difference in chemical composition between the two shipments used.

To express the total digestible nutrients in one single entity and at the same time allow for the greater value of the protein, the method of Petersen (*3*) as applied to Canadian conditions by Stothart (*4*) was used. The results were expressed in terms of dollars and cents per ton. The assumption was made, of course, that digestible carbohydrates have the same value per unit in both the hulls and the oat feed.

Table 9.—Digestible nutrients in pounds per 100 pounds of feed and money values in dollars per ton. Calculated from the results of digestion trials when the feeding stuffs under consideration were fed with hay. Expressed on moisture-free basis

	Oat Hulls calculated from experiments AN 13–2 and AN 13–5, including animal 84387J			Oat Hulls calculated from experiments AN 13–2 and AN 13–5, omitting animal 84387J			Vim Oat Feed calculated from experiment 3		
	Mean of seven values	Co-efficient of vari-ation	Stand-ard Error of mean	Mean of five values	Co-efficient of vari-ation	Stand-ard Error of mean	Mean of four values	Co-efficient of vari-ation	Stand-ard Error of mean
Digestible crude protein	—	—	—	—	—	—	2.38	4.90	±0.06
Digestible crude fibre	11.75	18.77	±0.83	10.71	7.79	±0.37	5.39	13.79	±0.37
Digestible N-free extract	15.30	15.23	±0.88	14.51	13.21	±0.86	17.46	7.20	±0.63
Total digestible nutrients*	27.27	16.08	±1.66	25.52	11.32	±1.29	25.59	8.22	±1.05
Value when barley is $23.00 and oil cake is $32.00	$6.53	16.10	±0.40	$6.11	11.33	±0.31	$7.18	7.49	±0.27
Value when barley is $23.00 and oil cake is $42.00	$5.09	16.15	±0.31	$4.76	11.23	±0.24	$6.94	6.84	±0.24
Value when barley is $33.00 and oil cake is $32.00	$11.39	16.05	±0.69	$10.66	11.23	±0.54	$10.65	8.24	±0.44

* That the average values for the total digestible nutrients do not agree with the values calculated from the average values of the individual nutrients is due to the fact that in some cases values for digestible ether extract were obtained. These values were included in the calculations of the total digestible nutrients for those cases.

There is no significant difference between the total digestible nutrients per 100 pounds in oat hulls and Vim Oat Feed. The oat hulls contain a significantly higher quantity of digestible crude fibre, whereas the oat feed contains a higher content of digestible nitrogen-free extract. In this latter case, the difference is not significant when animal 84387J is included. When this animal is omitted, however, the odds are approximately 30 : 1 that the difference is significant.

The values per ton are only significantly different when barley is quoted at $23.00 per ton and oil cake $42.00. This is due to the high price accredited to digestible protein, namely, 5.48 cents per pound as compared with 0.933 cents for the carbohydrates. The oat feed is credited with 2.38 lbs. digestible crude protein per 100 lbs., whereas it was not possible to estimate the digestible protein in oat hulls. This does not imply of course that the latter is necessarily devoid of digestible protein.

Similar calculations are presented in Table 10 for the condition where the feeds were fed alone in the ration. In this case the deviations observed in the values for the Oat Feed are the result of both the variations in the individual coefficients of digestibility and the difference in chemical composition between the two lots of feed used.

From an examination of Table 10, it will be seen that the two feeds are similar, the only significant difference being in the case of the digestible crude fibre, which is higher in the oat hulls than in the Vim Oat Feed. As before, with barley at $23.00 per ton and oil cake at $42.00, the Vim Oat Feed tends to have a higher value.

TABLE 10.—DIGESTIBLE NUTRIENTS PER 100 POUNDS OF FEEDING STUFF AND VALUE PER TON AS CALCULATED FROM DIGESTION TRIALS IN WHICH THE FEEDS WERE FED ALONE IN THE RATION, EXPRESSED ON THE DRY MATTER BASIS

	Oat Hulls, calculated from experiment AN 13–3			Vim Oat Feed, calculated from experiment AN 7–1 and 7–2		
	Mean of four values	Co-efficient of variation	Standard Error of mean	Mean of four values	Co-efficient of variation	Standard Error of mean
Digestible crude protein	—	—	—	2.41	32.12	±0.39
Digestible ether extract	0.26	10.17	±0.01	1.41	13.42	±0.10
Digestible crude fibre	18.16	2.80	±0.25	11.13	4.13	±0.23
Digestible N-free extract	21.34	5.35	±0.57	19.85	7.17	±0.71
Total digestible nutrients	40.08	3.86	±0.77	36.56	8.25	±1.51
Value when barley is $23.00 and oil cake is $32.00	$9.60	3.89	±0.19	$9.82	10.71	±0.53
Value when barley is $23.00 and oil cake is $42.00	$7.48	3.87	±0.14	$9.01	14.01	±0.64
Value when barley is $33.00 and oil cake is $32.00	$16.76	3.85	±0.32	$15.22	8.22	±0.64

SUMMARY AND CONCLUSIONS

Digestibility trials were undertaken with grade Shorthorn steers upon oat hulls, coarsely ground, with and without a basal ration of hay and upon Vim Oat Feed, finely ground, when fed alone in the ration. From the results of these trials, the coefficients of digestibility, total digestible nutrients and values per ton of these feeding stuffs were calculated. These calculations were supplemented with similar values obtained from the previous work (*5*) and an estimation made of the relative values of the two feeds. The following conclusions have been derived as to these comparative values.

(1) In the case of each feeding stuff, the coefficients of digestibility as calculated from a mixture of the feed with hay were lower than those obtained when the feeding stuff was fed alone.

(2) The digestibility of oat hulls was similar, in degree, to that of Vim Oat Feed. Certain differences were noted, however, with regard to the individual nutrients. The digestibility of the crude fibre of the oat hulls was markedly higher than that of the Vim Oat Feed, whereas the digestibility of the nitrogen-free extract was lower though not quite significantly. Further, it was not possible under the conditions of the experiments to determine a coefficient of digestibility for the nitrogen of oat hulls, whereas the coefficient for the nitrogen of the Vim Oat Feed was in the neighbourhood of 50.

(3) There was no significant difference between the total digestible nutrients per 100 lbs. in Vim Oat Feed and those in the oat hulls.

(4) Differences in the individual digestible nutrients per 100 lbs. corresponding to the differences in the coefficients of digestibility of the same nutrients were noted.

(5) When the digestible nutrients in the two feeds were expressed on a money basis, a significant difference in value was only noted when digestible protein was credited with a relatively high price. This difference, in favour of the Vim Oat Feed, was small but significant. It is due, in part, to the lack of a satisfactory coefficient of digestibility for the nitrogen of the oat hulls.

(6) Based upon these digestibility trials it is concluded that the feeding value of oat hulls is similar to that of Vim Oat Feed. Vim Oat Feed may be given a slightly higher rating because of the content of about 2 lbs. of digestible protein per 100 lbs., as compared with an undetermined smaller value for the oat hulls.

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Appendix

Table 11.—Composition of Feeding Stuffs

——	Moisture	Ash	Protein (N × 6.25)	Ether extract	Crude fibre	N-free extract
Vim Oat Feed						
Experiment AN 7–1	5.92	5.81	3.82	1.76	30.55	52.14
Experiment AN 7–2	7.47	6.89	5.47	1.99	29.27	48.91
Hay						
Experiment AN 13–1	7.89	7.88	10.18	1.85	28.50	43.70
Experiment AN 13–2	7.76	8.38	9.41	2.07	27.25	45.13
Experiment AN 13–4	9.15	6.81	9.88	2.43	28.27	43.46
Experiment AN 13–5	8.76	6.79	10.65	2.40	28.63	42.77
Oat Hulls						
Experiment AN 13–2	6.71	5.37	1.75	0.51	32.82	52.84
Experiment AN 13–3	6.44	5.37	1.75	0.51	33.52	52.42
Experiment AN 13–5	8.49	5.56	1.72	0.64	33.14	50.45

TABLE 12.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF HAY IN EXPERIMENT AN 13–1

(Weights in kilogrammes. Collection period of 12 days)

——	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-Free extract
No. 84387J						
In feed	82.899	75.807	1.465	1.665	25.650	39.330
In feces	33.359	28.034	0.594	1.168	11.027	12.257
Digested	49.540	47.773	0.871	0.497	14.623	27.073
Coefficient	59.8	63.0	59.0	29.9	57.0	68.8
No. 84381J						
In feed	82.899	75.807	1.465	1.665	25.650	39.330
In feces	33.694	28.112	0.569	1.277	10.991	12.389
Digested	49.205	47.695	0.896	0.388	14.659	26.941
Coefficient	59.4	62.9	61.2	23.3	57.2	68.5
*No. 84424J**						
In feed	75.990	69.490	1.343	1.526	23.513	36.053
In feces	30.707	25.618	0.554	1.078	10.290	11.011
Digested	45.283	43.872	0.789	0.448	13.223	25.042
Coefficient	59.6	63.1	58.8	29.4	56.2	69.5
No. 84422J						
In feed	82.899	75.807	1.465	1.665	25.650	39.330
In feces	33.406	27.610	0.568	1.286	10.275	12.485
Digested	49.493	48.197	0.897	0.379	15.375	26.845
Coefficient	59.7	63.6	61.2	22.8	60.0	68.3

*Collection period of 11 days.

TABLE 13.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS IN EXPERIMENT AN 13–2

(Weights in kilogrammes. Collection period of 12 days)

——	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-Free extract
No. 84387J						
In feed	88.865	81.723	1.077	1.519	27.831	45.638
In feces	42.344	36.612	0.489	1.003	12.918	19.788
Digested	46.521	45.111	0.588	0.516	14.913	25.850
Coefficient	52.4	55.2	54.6	34.0	53.6	56.6
Digested from hay	36.283	34.979	0.598	0.361	10.359	20.493
Digested from hulls	10.238	10.132	—	0.155	4.554	5.357
Intake in hulls	27.987	26.376	0.084	0.153	9.846	15.852
Coefficient for hulls	36.6	38.4	—	—	46.3	33.8
No. 84381J						
In feed	88.865	81.723	1.077	1.519	27.831	45.638
In feces	45.198	39.431	0.498	0.934	14.677	20.802
Digested	43.667	42.292	0.579	0.585	13.154	24.836
Coefficient	49.2	51.8	53.8	38.5	47.3	54.4
Digested from hay	36.283	34.979	0.598	0.361	10.359	20.493
Digested from hulls	7.384	7.313	—	0.224	2.795	4.343
Intake in hulls	27.987	26.376	0.084	0.153	9.846	15.852
Coefficient for hulls	26.4	27.7	—	—	28.4	27.4

TABLE 13.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS IN EXPERIMENT AN 13–2—*Concluded*

(Weights in kilogrammes. Collection period of 12 days)

——	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-Free extract
No. 84424J						
In feed	116.852	108.099	1.161	1.672	37.677	61.490
In feces	65.760	57.622	0.591	1.080	20.977	31.959
Digested	51.092	50.477	0.570	0.592	16.700	29.531
Coefficient	43.7	46.7	49.1	35.4	44.3	48.0
Digested from hay	36.283	34.979	0.598	0.361	10.359	20.493
Digested from hulls	14.809	15.498	—	0.231	6.341	9.038
Intake in hulls	55.974	52.752	0.168	0.306	19.692	31.704
Coefficient for hulls	26.5	29.4	—	75.5	32.2	28.5
No. 84422J						
In feed	116.852	108.099	1.161	1.672	37.677	61.490
In feces	65.160	57.506	0.564	1.166	20.688	32.073
Digested	51.692	50.593	0.597	0.506	16.989	29.417
Coefficient	44.2	46.8	51.4	30.3	45.1	47.8
Digested from hay	36.283	34.979	0.598	0.361	10.359	20.493
Digested from hulls	15.409	15.614	—	0.145	6.630	8.924
Intake in hulls	55.974	52.752	0.168	0.306	19.692	31.704
Coefficient for hulls	27.5	29.6	—	47.9	33.7	28.2

TABLE 14.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS IN EXPERIMENT AN 13–3

(Weights in kilogrammes. Collection period of 12 days)

——	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-Free extract
No. 84387J						
In feed	84.204	79.371	0.252	0.459	30.168	47.178
In feces	51.187	46.423	0.263	0.256	14.856	29.699
Digested	33.017	32.948	—	0.203	15.312	17.479
Coefficient	39.2	41.5	—	44.2	50.8	37.1
No. 84381J						
In feed	84.204	79.371	0.252	0.459	30.168	47.178
In feces	51.597	47.244	0.240	0.222	15.484	30.152
Digested	32.607	32.127	0.012	0.237	14.684	17.026
Coefficient	38.7	40.5	4.8	51.6	48.7	36.1
No. 84424J						
In feed	84.204	79.371	0.252	0.459	30.168	47.178
In feces	49.822	45.607	0.240	0.233	14.655	29.113
Digested	34.382	33.764	0.012	0.226	15.513	18.065
Coefficient	40.8	42.5	4.8	49.2	51.4	38.3
No. 84422J						
In feed	84.204	79.371	0.252	0.459	30.168	47.178
In feces	48.565	44.103	0.227	0.271	14.511	27.920
Digested	35.639	35.268	0.025	0.188	15.657	19.258
Coefficient	42.3	44.4	9.9	41.0	51.9	40.8

TABLE 15.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF HAY IN EXPERIMENT AN 13–4

(Weights in kilogrammes. Collection period of 12 days)

——	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-Free extract
No. 84387J						
In feed	81.765	75.636	1.423	2.187	25.443	39.114
In feces	32.979	29.417	0.537	1.276	11.605	13.397
Digested	48.786	46.219	0.886	0.911	13.838	25.717
Coefficient	59.7	61.1	62.3	41.6	54.4	65.8
No. 84381J						
In feed	81.765	75.636	1.423	2.187	25.443	39.114
In feces	33.476	29.811	0.521	1.274	11.984	13.458
Digested	48.289	45.825	0.902	0.913	13.459	25.656
Coefficient	59.1	60.5	63.4	41.8	52.9	65.6

TABLE 16.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF OAT HULLS IN EXPERIMENT AN 13–5

(Weights in kilogrammes. Collection period of 12 days)

——	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-Free extract
No. 84387J						
In feed	87.671	81.522	1.207	1.776	28.838	43.363
In feces	43.927	39.795	0.502	0.989	15.294	20.579
Digested	43.744	41.727	0.705	0.787	13.544	22.784
Coefficient	49.9	51.2	58.4	44.3	47.0	52.5
Digested from hay	35.770	33.888	0.708	0.661	10.147	18.546
Digested from hulls	7.974	7.839	—	0.126	3.397	4.238
Intake in hulls	27.453	25.785	0.082	0.192	9.942	15.135
Coefficient for hulls	29.1	30.4	—	65.6	34.2	28.0
No. 84381J						
In feed	87.671	81.522	1.207	1.776	28.838	43.363
In feces	46.123	41.562	0.508	1.150	15.831	21.531
Digested	41.548	39.960	0.699	0.626	13.007	21.832
Coefficient	47.4	49.0	57.9	35.3	45.1	50.4
Digested from hay	35.770	33.888	0.708	0.661	10.147	18.546
Digested from hulls	5.778	6.072	—	—	2.860	3.286
Intake in hulls	27.453	25.785	0.082	0.192	9.942	15.135
Coefficient for hulls	21.1	23.6	—	—	28.6	21.7
No. 84424J						
In feed	87.671	81.522	1.207	1.776	28.838	43.363
In feces	46.197	41.474	0.531	1.111	15.939	21.261
Digested	41.474	40.048	0.676	0.665	12.899	22.102
Coefficient	47.3	49.1	56.0	37.4	44.7	51.0
Digested from hay	35.770	33.888	0.708	0.661	10.147	18.546
Digested from hulls	5.704	6.160	—	—	2.752	3.556
Intake in hulls	27.453	25.785	0.082	0.192	9.942	15.135
Coefficient for hulls	20.8	23.9	—	—	27.7	23.5

TABLE 17.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF VIM OAT FEED IN EXPERIMENT AN 7–2

(Weights in kilogrammes. Collection period of 12 days)

——	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-Free extract
No. 84424J						
In feed	83.277	77.076	0.788	1.791	26.343	44.019
In feces	52.027	46.530	0.390	0.456	16.810	27.024
Digested	31.250	30.546	0.398	1.335	9.533	16.995
Coefficient	37.5	39.6	50.5	74.5	36.2	38.6
No. 84422J						
In feed	83.277	77.076	0.788	1.791	26.343	44.019
In feces	50.918	45.463	0.366	0.513	16.712	26.074
Digested	32.359	31.613	0.422	1.278	9.631	17.945
Coefficient	38.9	41.0	53.6	71.4	36.6	40.8

RÉSUMÉ

ÉTUDES DE L'AVOINE À BÉTAIL VIM (VIM OAT FEED). 2. DIGESTIBILITÉ DE LA BALLE D'AVOINE. C. J. Watson, G. W. Muir, et W. M. Davidson, Ferme expérimentale centrale, Ottawa.

Ces essais de digestibilité portaient sur des bœufs métis Shorthorn; l'aliment employé était de la balle d'avoine grossièrement moulue, avec et sans ration de foin, ainsi que de l'avoine à bétail Vim (*Vim Oat Feed*), finement broyée et donnée seule dans la ration. Les coefficients de digestibilité, la somme totale d'éléments nutritifs digestibles et la valeur par tonne de ces aliments ont été calculés d'après les résultats de ces essais. Ces calculs ont été complétés par des chiffres semblables obtenus dans des recherches précédentes, et une évaluation a été faite de la valeur relative des deux aliments. Voici les conclusions auxquelles on a abouti en ce qui concerne les valeurs comparatives.

Pour chaque aliment, les coefficients de digestibilité, lorsque l'aliment était donné avec du foin, étaient plus faibles que ceux que l'on obtenait lorsque l'aliment était donné seul. La digestibilité de la balle d'avoine était semblable jusqu'à un certain point à celle de la *Vim Oat Feed*, mais certaines différences ont été notées en ce qui concerne les principes nutritifs individuels. La cellulose brute de la balle d'avoine avait une digestibilité beaucoup plus forte que celle de la *Vim Oat Feed;* par contre, la digestibilité de l'extrait libre d'azote était moins élevée, mais la différence n'était pas grande. Il n'a pas été possible dans les conditions de ces expériences de déterminer un coefficient de digestibilité pour l'azote de la balle d'avoine, tandis que le coefficient pour l'azote de la *Vim Oat Feed* était d'à peu près 50. Il n'y avait pas de différence significative entre la *Vim Oat Feed* et la balle d'avoine en ce qui concerne le total d'éléments nutritifs digestibles par 100 livres. Des différences ont été notées dans les éléments nutritifs digestibles pris séparément, par 100 livres, correspondant aux différences dans les coefficients de digestibilité des mêmes éléments. Lorsque les éléments digestibles nutritifs des deux aliments étaient exprimés sur une base monétaire, on ne notait une différence significative de valeur que lorsque la protéine digestible était comptée à un prix relativement élevé. La différence en faveur de la *Vim Oat Feed* était faible mais significative. Elle provient en partie du fait que l'on n'a pas un coefficient satisfaisant de digestibilité pour l'azote de la balle d'avoine. En se basant sur ces essais de digestibilité, on peut conclure que la valeur alimentaire de la balle d'avoine est semblable à celle de la *Vim Oat Feed.* La *Vim Oat Feed* peut être classée un peu plus haut que la balle d'avoine parce qu'elle renferme environ 2 livres de protéine digestible par 100 livres, tandis que la quantité trouvée dans la balle d'avoine est un peu plus faible.

RESISTANCE OF WILD OATS AND SOME COMMON CEREAL VARIETIES TO FREEZING TEMPERATURES[1]

O. S. Aamodt and A. W. Platt[2]
University of Alberta, Edmonton, Alberta
[Received for publication June 14, 1934]

Introduction

The difficulties involved in the eradication of winter annual weeds are generally appreciated. Weeds with the annual habit, that commence growth in the fall after the usual tillage operations have been discontinued and survive the freezing temperatures of the winter months, present a serious problem to the grower who wishes to sow his crop early in the spring. The question has been raised often as to whether wild oats *(Avena fatua)* is a winter annual.

The wild oat problem became rather acute in the fall of 1933 in north central Alberta. The four-year period 1929-32 was relatively dry in this region, especially the late summer and fall of 1932. Soil moisture conditions were unfavourable for the rapid germination of wild oat seeds lying in the soil during this period. In the spring of 1933 conditions were very favourable for growth and the seeds which had been accumulating in the soil, as a result of unfavourable conditions for germination in preceding years, produced one of the heaviest infestations of wild oats that the north central part of the Province has experienced. Dockage on wheat for wild oats at the elevators frequently exceeded 25%.

Moisture was very plentiful in the fall of 1933, and favourable growing conditions were general until late November. Fields infested with wild oats produced a heavy crop of seedlings. With this situation many farmers who hold the belief that wild oats is a winter annual naturally became alarmed. Many others, who were uncertain regarding the growth habits of this weed, began to make inquiries regarding the possibility of wild oats surviving the winter. While the general opinion held by many farmers, and most technical workers, was that wild oats is not a winter annual, it seemed desirable to obtain more specific information regarding this character by conducting artificial freezing tests.

Methods

In addition to wild oats, a cultivated variety of oats, Victory, was included in the test for comparison; also commonly-grown varieties of other cereals, namely: Marquis, Red Bobs No. 222, Reward and Garnet spring wheats; Trebi barley; Prolific spring rye; Kharkov No. 22 winter wheat; and Dakold winter rye. The plants were grown in the greenhouse in wooden flats, 16 × 26 inches and 4 inches deep. Twenty seeds of each variety were sown in single rows across each flat. The plants were frozen in a large refrigerator chamber specially constructed for studying the effect of freezing temperatures on plants.[3] The flats were replicated three times in three tests (Experiments A, B and C), and six times in one test (Experiment D).

[1] Contribution from the Department of Field Crops, University of Alberta, Edmonton, Canada.
[2] Professor of Genetics and Plant Breeding and Field Assistant, respectively.
[3] The equipment for the refrigerating plant was furnished by the National Research Council of Canada.

The plants were hardened off and then exposed to low temperatures at the 3–4 leaf stage in Experiments A and B; and in the 5-leaf stage in Experiment D, according to a regular procedure developed in experiments on the testing of winter wheats for resistance to killing at low temperatures.[4] The hardening procedure consisted of successive exposures in the refrigerators for two nights (5.00 p.m.–8.00 a.m.) at 30° F. (−1° C.), two nights at 25° F. (−4° C.) and two nights at 20° F. (−7° C.). Each day the plants were returned to the greenhouse where favourable conditions for growth existed. In this process, even though there are 12° F. (7° C.) of frost on the fifth and sixth nights, there was practically no injury to the foliage of the plants. On the seventh night the plants were exposed for four hours to a temperature of 5° F. (−15° C.) in Experiments A and B, to 10° F. (−12° C.) in Experiment C; and to −10° F. (−23° C.) in Experiment D.

The plants were returned to the greenhouse the day after freezing and allowed a period of two weeks for recovery before the notes on injury were taken. A measure of the degree of injury to the plants was obtained by calculating a survival index. The degree of foliage injury to each individual plant was noted on a scale of 1 to 5; "1" represented complete killing, "5" no injury, and "2," "3" and "4" intermediate degrees of injury. This index of injury from low temperatures appeared to be a better measure of the ability of various varieties to resist injury to the foliage, than a mere percentage of plants surviving. Many of the plants that showed life two weeks after freezing, would probably never have recovered at all under the most favourable conditions in the field in the spring. For this reason simply recording the percentage survival may be misleading. That there is a high degree of relationship between the survival index and the survival percentage, however, is illustrated by the significant correlation coefficient between these two values of $+ 0.908 \pm 0.019$. Since both of these values may be of interest, however, they are given in Table I.

Experimental Results

Experiment "A" was conducted in December, when there was very little natural sunlight. Even though this was supplemented by artificial light, the plants were very spindly as compared with the usual stocky growth in the field. The results obtained with the ten cereal varieties under test are given in Table I. The data for each variety are given as average survival index, per cent of plants surviving, and rank according to degree of injury based on the survival index. It is quite evident that wild oats is the most susceptible to injury by low temperatures and also has the least ability to survive. It held the lowest rank under both methods of scoring. Two of the replicated flats in this experiment are shown in Figure 1.

Owing to the lack of normal growth of the plants used in Experiment "A," it seemed desirable to repeat the tests with stronger plants. This was done later in the winter when light conditions were more favourable for the production of strong, healthy plants. These tests were conducted on a more extensive scale and divided into three experiments. Experiment "B" was a repetition of Experiment "A," except for the difference in the

[4] Unpublished results.

FIGURE 1.—Survival of Dakold (1) winter rye, Kharkov No. 22 (2) winter wheat, Prolific (3) spring rye, Victory (4) oats, Wild oats (5), Trebi (6) barley, Marquis (7), Reward (8), Red Bobs No. 222 (9) and Garnet (10) spring wheats, when hardened and then frozen at 5° F. (−15° C.) for four hours. Photographed two weeks after freezing.

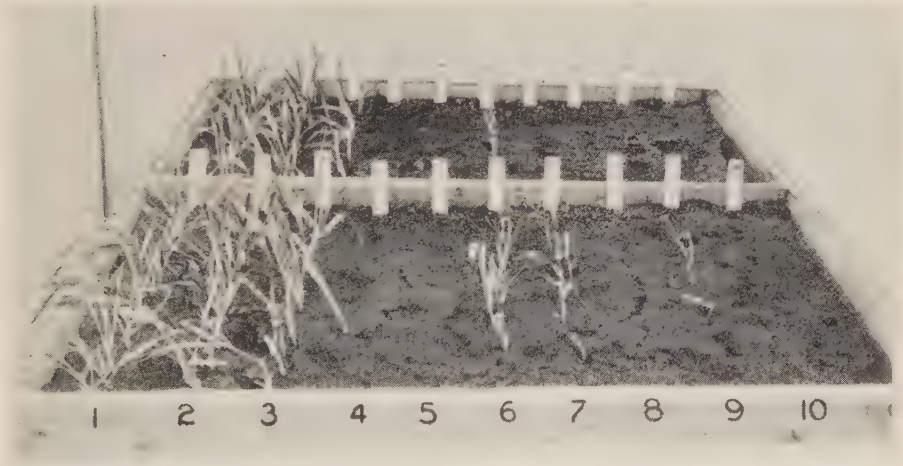

FIGURE 2.—Survival of Dakold (1) winter rye, Kharkov No. 22 (2) winter wheat, Prolific (3) spring rye, Victory (4) oats, Wild oats (5), Trebi (6) barley, Marquis (7), Reward (8), Red Bobs No. 222 (9) and Garnet (10) spring wheats, when hardened and then frozen at −10° F. (−23° C.) for four hours. All dead plants and leaves removed before photographing two weeks after freezing.

growth of the plants. The data obtained are given in Table I. The results are very similar to those obtained in the first experiment, indicating that the inherent differences of the various cereals to resist injury by low temperatures are expressed approximately as well in this case by the spindly plants as by the stocky ones. Wild oats again showed the greatest injury, but a little higher survival percentage than did cultivated oats.

TABLE 1.—SURVIVAL AND RELATIVE HARDINESS OF WILD OATS AND SOME CEREAL VARIETIES WHEN EXPOSED TO VARIOUS FREEZING TEMPERATURES IN THE SEEDLING STAGE

Variety	*C.A.N.	Experiment A. 5° F. (−15° C.) Survival			Experiment B. 5° F. (−15° C.) Survival			Experiment C. 10° F. (−12° C.) Survival			Experiment D. −10° F. (−23°C .) Survival			Average Survival		
		Index	Per cent	Rank	Index	Per cent	Rank	Index	Per cent	Rank	Index	Per cent	Rank	Index	Per cent	Rank
Dakold—winter rye	—	88.2	100.0	1	84.5	100.0	1	79.3	100.0	3	70.5	95.9	1	80.6	99.0	1
Kharkov No. 22—winter wheat	2360	85.8	100.0	2	71.3	88.5	3	68.5	100.0	4	70.1	94.7	2	73.9	95.8	2
Prolific—spring rye	—	36.6	79.3	5	71.9	90.8	2	88.4	95.6	1	31.2	58.0	3	57.0	80.9	3
Trebi—barley	753	39.4	92.1	4	64.1	95.7	4	87.2	100.0	2	11.8	28.1	4	50.6	79.0	4
Red Bobs No. 222 spring wheat	1637	51.7	89.6	3	59.4	82.3	5	68.5	96.2	5	1.2	4.6	6	45.2	68.2	5
Marquis spring wheat	1621	29.2	60.4	7	49.7	68.8	6	63.1	80.8	7	2.7	10.8	5	36.2	55.2	6
Reward spring wheat	1509	32.9	70.3	6	39.2	58.8	7	64.2	77.7	6	0.0	0.0	7	34.1	51.7	7
Garnet spring wheat	1316	18.2	52.9	9	22.4	45.3	8	46.9	80.4	8	0.0	0.0	7	21.9	44.7	8
Victory—oats	284	25.4	73.2	8	15.3	20.4	9	42.3	71.1	9	0.0	0.0	7	20.8	41.2	9
Wild oats	—	8.6	27.4	10	13.8	25.1	10	16.7	27.5	10	0.0	0.0	7	9.8	20.0	10

*C.A.N.—Canadian Accession Number.

In certain years no natural hardening takes place in the field before the temperature drops sufficiently low to do considerable injury to volunteer plants, or crops of fall sown cereals. Experiment "C" was planned to test the susceptibility of the various cereals to low temperatures without previous hardening off. In this test the plants were placed in the refrigerator for two nights at 33° F. (1° C.) and then frozen for four hours at a temperature of 10° F. (−12° C.). The data obtained from this test are given as "Experiment C" in Table I.

The results obtained are in agreement with those obtained in the first two experiments, except that the two winter cereals, Kharkov No. 22 and Dakold, showed considerable foliage injury, in contrast to the hardier spring cereals, when not hardened previous to freezing. This is in agreement with the results obtained in the studies on hardiness in winter wheat and illustrates the need for a hardening-off process previous to exposure to the low or differential temperatures. In this experiment wild oats showed a considerably greater weakness in both foliage injury and non-survival. The difference between wild oats and Victory oats is especially interesting. The former has a survival index of 16.7 and a percentage survival of 27.5, while the latter had a survival index of 42.3 and a percentage survival of 71.1.

Since none of the temperatures used in the above experiments were completely lethal for any of the cereals, a fourth experiment was conducted to determine the relative susceptibility to killing at a temperature which was lethal to one or more of the varieties in the test. In the studies on winter hardiness referred to above, it was found that an exposure at −10° F. (−23° C.) for eight hours produced differential killing on segregating hybrid populations between spring and winter wheats. An exposure at this same temperature for twelve hours, produced differential killing on various winter wheat varieties; and at sixteen hours on wheat-rye hybrids and winter rye varieties.

In Experiment "D" the plants were hardened in the usual way, and then on the seventh night exposed to a temperature of −10° F. (−23° C.) for four hours. The data obtained are given as "Experiment D" in Table I.

Wild oats, Victory oats, Garnet and Reward wheats were completely killed in this test. Marquis and Red Bobs No. 222 were almost completely defoliated, but 10.8% and 4.6% respectively of the plants survived. These differences between the spring wheats are, in general, in agreement with previous extensive studies made on the resistance of spring wheat varieties to seedling injury by frost (1). The resistance of Marquis to frost injury has been noted in the Pacific Coast region, where it is sometimes grown as a fall wheat.

The foliage of Trebi barley and Prolific spring rye was severely injured, but 28.1% and 58.0%, respectively, of the plants survived. These results are in agreement with general field observations made by the senior writer, where it has been noted that both of these cereals are in general more resistant to spring and summer frosts than oats and spring wheat. The two winter cereals, as expected, showed some foliage injury but very

little killing. The results obtained in this experiment are illustrated in Figure 2.

Field Observations

Stands of wild oats were located in several fields in the fall of 1933. Fields showing a wide variety of conditions were selected for observation of not only wild oats, but also of the commonly grown spring cereals. In no instance, when growth had commenced in the fall, was there any indication of wild oats or cultivated varieties of spring wheat, oats or barley surviving the winter.

Discussion and Summary

The above experimental results and observations corroborate the view that there is little possibility, if any, of wild oats surviving the winter in central and northern Alberta when growth starts in the previous year. This fact lends support to the recommendation that stubble land should be disked in the fall in order to make conditions more favourable for the germination of wild oat seeds lying on the surface of the soil, and so promote their destruction by winter killing.

REFERENCE

1. Newton, R. Hearing on Garnet wheat. Proceedings of Select Standing Committee on Agriculture and Colonization, Canadian House of Commons, p. 104. April, 1932.

RÉSUMÉ

Résistance de la folle avoine et de certaines variétés ordinaires de céréales aux températures de congélation. O. S. Aamodt et A. W. Platt, Université de l'Alberta, Edmonton, Alberta.

Des expériences conduites dans des conditions contrôlées et s'appuyant sur des observations faites dans le champ, confirment l'idée que la folle-avoine n'a que peu ou point de chances de résister à l'hiver dans le centre et le nord de l'Alberta lorsqu'elle a commencé à pousser l'année précédente. Ce fait démontre l'utilité du système de lutte recommandé, qui consiste à disquer le chaume en automne pour créer des conditions soient plus favorables à la germination de la graine de la folle-avoine reposant à la surface du sol, provoquant ainsi sa destruction par l'hiver.

IMPROVEMENT OF RYE THROUGH INBREEDING[1]

R. F. Peterson[2]
Dominion Rust Laboratory, Winnipeg, Man.
[Received for publication March 20, 1934]

Introduction

Selection in self-fertilized lines is apparently the most logical method of improving naturally cross-pollinated crops. Among these crops, maize has been studied extensively in this respect, while rye has been much less investigated. The methods found suitable for maize can in general be applied to rye. Rye breeding, however, presents some special problems. Ordinary cultivated rye has been shown by many investigators to be partially self-sterile, the character being heritable, while maize is, as a rule, practically completely self-fertile. Rye grown under ordinary field conditions, where cross-pollination is not artificially interfered with, shows considerable unfruitfulness. Usually about one-third of the florets fail to set seed. In maize the seed setting is much higher. The lower seed setting in rye is probably due in part to the same heritable factors that bring about partial self-sterility and if this is the case it should be possible to improve the productivity of rye by using self-fertilized lines of high self-fertility as breeding stock. The purpose of the present paper is to report a study of the inbreeding method applied to rye with special reference to increasing seed setting and seed weight.

Literature Review

Since Rimpau (*17*), in 1877, demonstrated the partial self-sterility of cultivated rye, *Secale cereale* L., various studies have been made on the effect of self-pollination in this crop. It will be possible here to give only a brief review of those findings that have a direct bearing on the present study. It has been found (*e.g.*, *1*, *5*, *6*, *7*, *14*, *16*, *20*, *21*) that when individual plants of ordinary cultivated rye are isolated by space, or when the heads of single plants are covered with parchment bags or other agents suitable for enforcing self-pollination, the majority of the plants set little or no seed. A small proportion of the self-pollinated plants are usually highly self-fertile. The average seed setting in the first year of self-pollination has been, in most cases, well below 10%. Not only do plants within a variety differ in degree of self-fertility but varieties differ also. It has been found that self-fertility in rye is heritable and that it is possible to increase the degree of self-fertility of a variety by selection.

Continued inbreeding of rye without selection has been shown to result always in reduced vigour of the progeny on the average as compared with open pollinated material. Selection may bring out inbred strains showing no degeneration (*5*, *6*, *14*, *15*). Abnormalities such as chlorophyll deficiency and dwarfing often appear in inbred material.

[1] Abridgment of a thesis submitted to the Faculty of the Graduate School, University of Minnesota, in partial fulfilment of the requirements for the degree of Doctor of Philosophy, December, 1933. Contribution from the Division of Agronomy and Plant Genetics, Minnesota Agricultural Experiment Station, St. Paul, Minn. Paper No. 1261 of the Journal Series, Minnesota Agricultural Experiment Station.

[2] Graduate Assistant in the Division of Agronomy and Plant Genetics, Minnesota Agricultural Experiment Station, 1930–1932. Now Research Assistant at the Dominion Rust Research Laboratory, Winnipeg.

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Fruwirth (*13*) crossed two pure lines of rye and found that, when the F_1 was allowed to cross-pollinate, the yield excelled that of the parents.

Von Rumker and Leidner (*18*) showed that cross-fertilized plants gave a higher yield than the pure line parents.

Bredemann and Heuser (*4*) studied the effect of heterosis in rye by making crosses between varieties differing for yield. In the majority of cases the F_1 and F_2 excelled both parents in yield of grain and straw. The yield decreased in general in F_3 and F_4. In F_4 the yield was intermediate between those of the parents. Mechanical mixtures of equal parts of two varieties were tested in comparison with the parents, many combinations of varieties being made. In general the yield was approximately the same as the average of the parents. The hybrid generation from such mixtures showed an increased yield.

Schribaux (*19*) grew a mixture of equal parts of local and Petkus rye in comparison with the former. The mixture and several generations of its progeny gave a higher yield than the local rye.

Leith (*16*) found that over a three-year period approximately one third of the florets of rye grown in the field failed to set seed. There was much variation.

In most of the work reported on inbreeding of rye, parchment bags were used as an isolating agent. Space isolation appears to allow of a more accurate measure of fertility but is impractical if many plants are to be tested. Cloth wrappings of various kinds have proved unreliable. Berg (*3*) has used the method of sealing the glumes with gum arabic.

Experimental Material

The studies here reported were confined almost entirely to Minnesota No. 2 rye which originated as a mass selection from Swedish rye. The materials used were inbred strains of Minnesota No. 2 developed at University Farm, St. Paul, by Dr. H. K. Hayes and Dr. H. E. Brewbaker. Dr. Hayes began isolating the strains in 1916, using space isolation, and started self-fertilization work in 1920. Dr. Brewbaker continued the study with the same material in the fall of 1921. Glassine bags were used for several years, although, from 1925 until the present report, parchment bags were used, and, as a rule, several spikes of each selfed plant were enclosed in a bag. Brewbaker (*5*) found that most of the self-pollinated plants were highly self-sterile, but that a small proportion of them showed relatively high self-fertility. Strains were maintained year after year by successive selfing. Selections were made each year from plants showing high self-fertility and good seed, and several strains apparently breeding true for high self-fertility were isolated. Several strains of low self-fertility were produced also by selecting in successive years for that character. In 1926 the results up to that time were published (*5*). In 1929 Dr. Brewbaker made crosses between self-pollinated strains representing low and high levels of seed setting to study the effect of various combinations, and in 1930 he selfed the F_1 plants. In 1931 the material was made available to the writer for studies in fertility and seed setting. Table 1 gives the history of the strains used in the crosses. In the column headed "Parent plant" is given the percentage seed setting of the plants used to obtain progeny the following year. Three of the 9 strains were first selfed in 1921,

TABLE 1.—PERCENTAGE SEED SETTING IN SELFED STRAINS OF MINNESOTA NO. 2 RYE. HISTORY OF STRAINS USED IN CROSSES FOR FERTILITY STUDIES

Number plants selfed	Average	Range	Parent plant	Number plants selfed	Average	Range	Parent plant	1929 culture number
1923 % Seed setting				1924 % Seed setting				
9	1.0	0.0 – 3.0	51.7*	12	9.2	0.0 – 25.4	25.4	348
6	4.7	0.0 – 25.7	2.1	4	29.7	1.5 – 76.1	76.1	355
11	5.0	0.0 – 19.5	7.5	11	19.5	0.0 – 76.8	76.8	366
16	7.6	0.0 – 53.1	53.1	17	12.6	0.0 – 66.2	37.5	325
15	1.5	0.0 – 6.0	57.3*	8	12.6	0.0 – 81.3	81.3	338
10	2.7	0.0 – 16.4	16.4	13	9.2	0.8 – 43.4	43.4	377
12	2.5	0.0 – 12.5	12.2	6	10.2	0.0 – 34.0	34.0	389
1925 % Seed setting				1926 % Seed setting				
4	20.3	2.0 – 62.9	62.9	4	55.7	27.3 – 85.9	66.3	348
4	51.5	41.2 – 60.0	60.0	3	29.8	20.5 – 35.0	35.0	355
5	31.4	0.0 – 69.0	69.0	8	24.7	0.0 – 47.4	47.4	366
4	2.6	0.0 – 6.0	6.0	9	8.2	0.0 – 58.9	10.2	321
4	3.2	0.5 – 7.7	3.6	9	4.3	0.0 – 21.1	21.1	325
3	1.2	0.0 – 2.9	1.9	5	7.2	1.3 – 28.8	28.8	338
							1.3	
4	1.3	0.8 – 1.6	1.4	5	9.9	0.0 – 56.7	1.8	377
5	9.2	0.0 – 16.7	16.7	12	1.7	0.0 – 5.4	5.4	389
1927 % Seed setting				1928 % Seed setting				
5	84.7	67.5 – 98.9	67.5	1	70.5	—	70.5	348
8	23.4	0.0 – 60.0	53.5	7	60.6	33.3 – 95.9	95.9	355
2	59.9	36.9 – 72.9	72.9	3	57.4	52.1 – 67.5	52.1	366
2	59.9	36.9 – 72.9	72.9	3	57.4	52.1 – 67.5	52.5	367
6	3.5	0.0 – 7.3	1.6	—	—	—	—	321
11	3.7	0.3 – 9.0	9.0	—	—	—	—	325
5	3.9	0.6 – 12.5	12.5	9	1.2	0.0 – 6.8	3.7	338
3	5.0	0.0 – 14.7	14.7	—	—	—	—	377
4	2.2	1.0 – 3.7	3.7	—	—	—	—	389
1929 % Seed setting				No. years selfed before 1929				
17	51.5	32.1 – 97.8		1 + 5‡	High self-fertility			348
8	63.2	42.7 – 78.3		7	High self-fertility			355
4	32.2	23.1 – 46.2		8	High self-fertility			366
7	39.6	9.3 – 68.1		8	High self-fertility			367
2	42.9	3.6 – 82.2		3	Low self-fertility			321
9	13.4	0.9 – 72.6†		5	Low self-fertility			325
5	0.5	0.0 – 2.5		1 + 5	Low self-fertility			338
9	0.9	0.0 – 3.3		7	Low self-fertility			377
3	7.5	2.5 – 13.3		2 + 5	Low self-fertility			389

*This plant was sibbed. †The range was 0.9–8.8 with the exception of one plant which was 72.6. ‡The plus sign indicates 1 year sibbed, *e.g.*, 1 + 5 indicates 1 year selfed followed by 1 year sibbed and this followed by 5 years selfed.

4 in 1922, 1 in 1923 and 1 in 1925. All strains came from different original selections in Minnesota No. 2 rye, except cultures 366 and 367. Both of these came from the same 1928 culture but in no case were they both used in the same cross in 1929. Hence all crosses were between strains that had been kept separate since the original selections were made from

Minnesota No. 2 rye. One strain (No. 410) which was used in one of the crosses was a highly self-fertile selection from the variety Abruzzes obtained from Dr. E. B. Mains of Purdue University. It had been selfed 8 years.

Experimental Methods

In self-pollinating rye plants the method used by Brewbaker (*5*) was followed. Several heads of a plant were enclosed in a parchment bag shortly before anthesis and the bag was tied to a stake for support. The heads were left thus enclosed until ripe. This method makes possible the isolation of a large number of plants in a small space but it has some disadvantages. Less seed is set than under conditions of space isolation. Moreover, when a large amount of material is handled, it is impossible to make certain that no off-pollination takes place. The later plants are bagged when there is a great deal of pollen in the air. Some pollen grains may become lodged in the glumes of heads before they are covered and bring about fertilization later when the stigma becomes receptive. The occasional occurrence of apparently self-fertile plants in highly self-sterile strains might be explained on this basis.

In determining the percentage of florets setting seed, only the lateral florets were considered. Only occasionally was a seed found in the third floret of a spikelet.

Experimental Results

Increasing self-fertility

A general idea of the rate of increase of self-fertility when strains of rye are selfed in successive years and selection is practised may be obtained from the strains selfed in 1932. These ranged from strains that had been selfed for the third time up to others that were selfed for the twelfth time. Table 2 summarizes the data.

Table 2.—Percentage seed setting for selfed strains in 1932

No. of generations selfed	No. of strains*	Average per cent of lateral florets setting seed
3	28	4.8
5	7	19.7
6	58	29.1
7	12	43.1
8	3	46.6
11	4	30.6
12	11	41.8

*The average number of plants selfed per strain was 4.5.

The material consisted of strains derived from those represented in Table 1 as well as strains from Dr. Hayes' breeding plots developed in the same way and which he kindly made available for this summary. Strains developed by sibbing as well as selfing are not included in Table 2.

It will be seen from this table, as well as Tables 1, 3 and 4 that in strains that have been selected for high self-fertility for several years the average percentage seed setting is usually between 20 and 60. In strains that have been selected for several years for low self-fertility the average percentage seed setting is usually below 10. Although the former group is far from being completely self-fertile, it is of definitely higher self-fertility than the latter group. Hence, for convenience and simplicity the terms high self-fertility and low self-fertility are used in this paper in referring to groups of this kind. It will be noted that there is great variability of

seed setting in the high self-fertility group. Part of this variability may be due to environmental factors alone, for covering the heads of self-fertile varieties of small grains causes a variation in seed setting in some cases.

F_1 RESULTS—1930

Plants of several of the high and low fertility strains and the F_1 progeny of the 1929 crosses were selfed. These crosses may be grouped as follows

TABLE 3.—FREQUENCY DISTRIBUTION OF SELF-POLLINATED PLANTS FOR PERCENTAGE SEED SETTING IN 1930. SELFED LINES AND F_1 PROGENGY OF 1929 CROSSES

1929 origin (Plant No.)	0	0.1 to 9.9	10.0 to 19.9	20.0 to 29.9	30.0 to 39.9	40.0 to 49.9	50.0 to 59.9	60.0 to 69.9	70.0 to 79.9	80.0 to 89.9	90.0 to 99.9	Total plants	Average percentage seed setting †
High fertility lines													
366–4						1	3					4	52.8
348–5					1							1	31.1
348–6								1		1		2	72.7
348–7				3	3	1	3	2				12	42.5
348–14				1		1		1				3	47.1
348–22	1				4		1	1				7	36.2
348–23	1				1							2	16.4
355–5	2	3	1				1					7	12.1
Low fertility lines													
321–2	5											5	0.0
325–9	1	1										2	0.2
325–10	1											1	0.0
325–3		2		1								3	7.7
325–4	1	1										2	4.5
325–7	1											1	0.0
377–9	2		1									3	6.0
389–3	2	2										4	0.4
389–5	1	2										3	0.8
High × High F_1													
355–5 × 348–1	1						1	4	1			7	56.2
366 × 348		1			1	1		3	1	5		12	63.3
348–6 × 410–3*	1		1			2				2		6	46.1
High × Low F_1 (including Low × High)													
377–9 × 348–11	4	1	3	2	4	4	3	3	3	1		28	39.4
377–5 × 355–5	2		1	1		3		1				8	29.8
367–7 × 389–1										3	4	7	91 9
338–1 × 367–1	1								5	6	3	15	79.1
366–8 × 321–2	3		1			1		2	3	2		12	47.8
366–5 × 321–2									1			1	74.1
366–5 × 325–10	4	3					2	1	2	1	1	14	37.9
325–9 × 348–14	3	1			1			5	8	1		19	56.8
325–10 × 348–1							4	2				6	57.9
Low × Low F_1													
338–5 × 321–2	9	12	2	2								25	5.2
325–9 × 321–2	8	11										19	1.5

* Minnesota No. 2 × Abruzzes.

† The averages given in this and the following tables are calculated from actual values and not from the groupings used in the tables.

with reference to the degree of self-fertility of the parents:

High × High[1]
Low × Low
High × Low
Low × High.

The average percentage seed setting of crossed plants in 1929 was as follows:—

High × High	34.7	(26 crosses)
High × Low	30.8	(12 crosses)
Low × High	42.8	(15 crosses)
Low × Low	74.3	(2 crosses, 78.6 and 70.0).

The differences are probably largely due to differences in technique as several assistants were employed, but the data clearly show that the Low × Low crosses were fertile. Table 3 gives the percentage seed setting of selfed plants in the various groups in 1932. The variability within the high fertility lines and F_1 progenies would seem to be due chiefly to environmental factors. With variability as great as this, one could not hope to establish definite ratios in the segregating F_2 progenies. The High × High F_1 plants are similar to the high fertility parents for seed setting and the Low × Low plants are similar to the low fertility parents. This is interesting in view of the fact that the Low × Low cross was quite fertile. The somewhat higher seed setting in the High × High F_1 group as compared with the parents may be due to hybrid vigour. The High × Low F_1 plants resemble the high fertility rather than the low fertility plants for seed setting. There would appear to be two possible interpretations of these data. If the partial sterility is a true gametic sterility then high fertility is apparently dominant. The sterility may, however, be due to differential pollen tube growth as in *Nicotiana* and several other genera (*8*). The fact that the Low × Low cross was fertile but that the selfed F_1 progeny of this cross was highly sterile favours the latter hypothesis. This will be dealt with in the discussion at the end of the paper.

F_2 RESULTS—1931

In 1931 the following material was grown and selfed:—

Strains of high self-fertility,
Strains of low self-fertility,
F_2 progeny of 1929 crosses.

The F_2 progeny were grown from seed of selfed F_1 plants. The seed setting of the high and low fertility lines (see Table 4) was, in general, similar to that of the previous year except that the former had somewhat lower seed setting in 1931 than in 1930. The single plant of high fertility in the low fertility class may be due to a single floret being accidentally open-pollinated the previous year. No clear-cut Mendelian ratios can be derived from the F_2 progenies. Again there is an apparent dominance of high over low self-fertility. Heribert-Nilsson (*14*), however, obtained some evidence based on a small number of plants that self-sterility in rye is dominant over self-fertility. The same interpretations as given in the previous section would apply here.

[1] In naming the crosses, "High" and "Low" will mean "high self-fertility" and "low self-fertility" respectively.

TABLE 4.—FREQUENCY DISTRIBUTION OF SELF-POLLINATED PLANTS FOR PERCENTAGE SEED SETTING IN 1931. SELFED LINES AND F_2 PROGENY OF 1929 CROSSES

No. of 1931 cultures	1929 origin (Plant No.)	0	0.1 to 9.9	10.0 to 19.9	20.0 to 29.9	30.0 to 39.9	40.0 to 49.9	50.0 to 59.9	60.0 to 69.9	70.0 to 79.9	80.0 to 89.9	90.0 to 99.9	Total plants	Average percentage seed setting
	High fertility lines													
4	366–4	9	34	17	10	2							72	9.9
3	348–6	2	3	8	8	10	6	1					38	27.6
9	348–7	1	1	2	3	2	4	4	3	1			21	40.9
4	348–14			4	2	6	3		3				18	35.6
6	348–22	1	9	3			1		4	2	1		21	28.4
1	348–23			1									1	15.3
2	355–5		1	1									2	6.8
	Low fertility lines													
3	325–3	15	18										33	1.3
1	325–4	1	3					1					5	12.0
	High × High F_2													
4	355–2 × 348–1	1	2	2	1	1	3		2				12	30.0
6	355–5 × 348–1	2	2	9	29	65	76	70	28	10	1	1	293	44.7
8	366–4 × 348–7	1	2	4	13	20	42	71	64	45	5	1	268	55.6
1	348–6 × 410–3*		2		3	3	7	5	5	3			28	46.8
	High × Low F_2													
18	377–9 × 348–11	4	20	35	51	91	90	90	34	9	3		427	40.2
1	377–5 × 355–5	1	6	8	9	19	6	5	3	1			58	32.1
7	367–7 × 389–9	2	15	26	35	37	45	35	21	6	1	2	225	38.5
6	338–1 × 367–1	4	8	20	21	38	29	53	34	18	3	2	230	45.3
	Low × Low F_2													
13	338–5 × 321–2	23	34	3		5	1		1	1			68	7.7
9	325–9 × 321–2	17	6		1					1			25	5.0

*Minnesota No. 2 × Abruzzes.

In the Low × Low F_2 group there are several rather highly self-fertile plants suggesting recessive factors for high self-fertility. It is possible that there are both dominant and recessive factors for this condition. In view of the small number of self-fertile plants in this group, however, it is not improbable that they are due to cross pollination in F_1 as explained under Experimental Methods.

Table 5 summarizes the F_1 and F_2 data. In order to give a general picture of the distribution of the progeny of crosses with respect to self-fertility, results of crosses of the same kind have been combined, even though the same factors may not be involved in each of the crosses. Figure 1 gives a graphical representation of the distributions given in Table 5.

The kernels of selfed low fertility lines were on the average smaller and lighter in weight than those produced by high fertility lines. The kernels of the Low × Low F_2 plants were also much smaller on the average than those of High × High F_2 and High × Low F_2. There was a difference in viability as well. When seeds were potted in the greenhouse, approximately 70% of those from Low × Low F_2 plants and 90% of those from High × High F_2 plants produced seedlings.

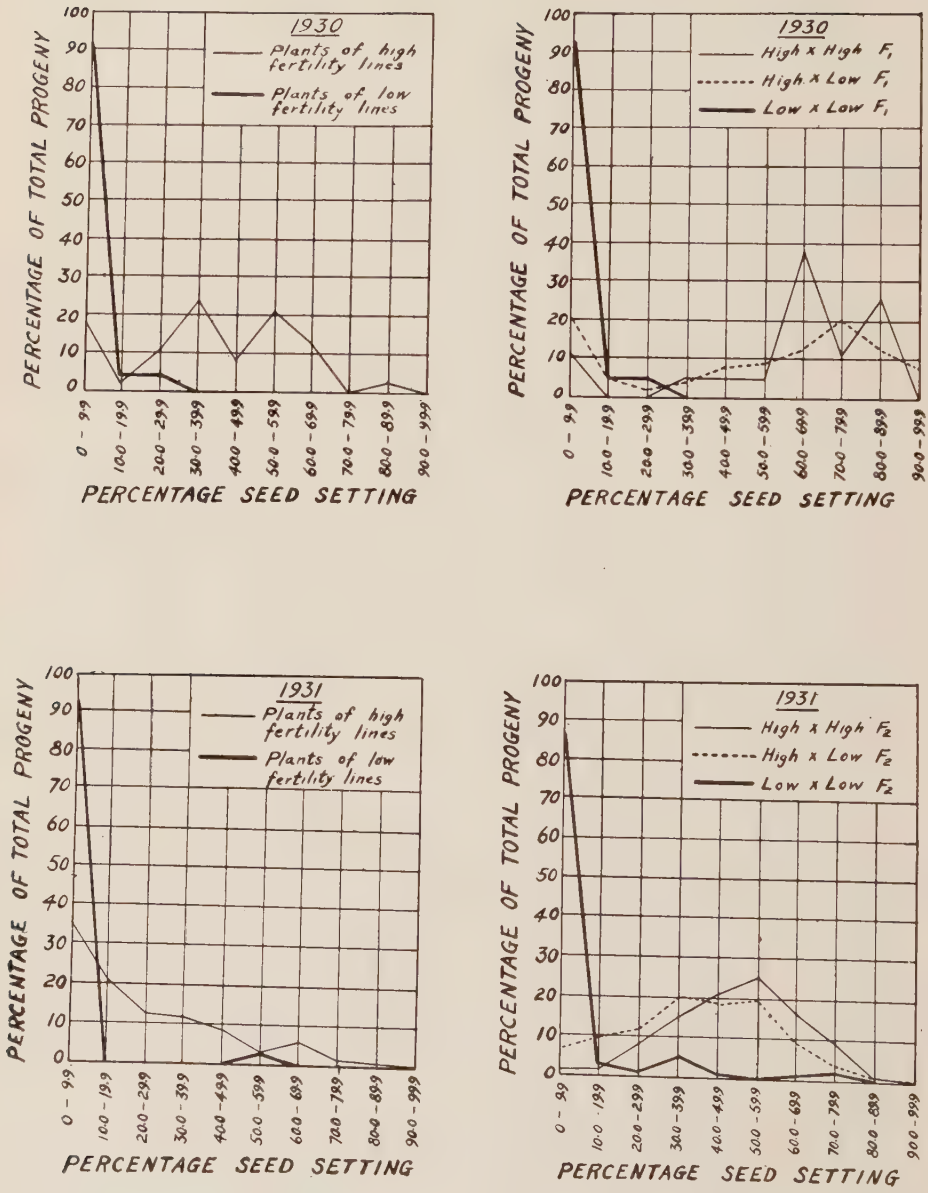

FIGURE 1. Distribution of selfed plants for percentage seed setting in strains of high and of low self-fertility and in progenies of crosses. Data from Table 5.

TABLE 5.—SUMMARIZED FREQUENCY DISTRIBUTION OF SELF-POLLINATED PLANTS FOR PERCENTAGE SEED SETTING FROM TABLES 2, 3 AND 4

Group	0	0.1 to 9.9	10.0 to 19.9	20.0 to 29.9	30.0 to 39.9	40.0 to 49.9	50.0 to 59.9	60.0 to 69.9	70.0 to 79.9	80.0 to 89.9	90.0 to 99.9	Total plants	Average
1930													
High fertility lines	4	3	1	4	9	3	8	5		1		38	37.1
Low fertility lines	14	8	1	1								24	2.3
High × High F_1	1	1			1	1	1	7	2	5		19	60.7
High × High F_1	1		1			2				2		6	46.1
High × Low F_1	17	5	5	3	5	8	9	14	22	14	8	110	52.5
Low × Low F_1	17	23	2	2								44	3.6
1931													
High fertility lines	13	48	36	23	20	14	5	10	3	1		173	22.5
Low fertility lines	16	21					1					38	2.7
High × High F_2	4	6	15	43	86	121	141	94	55	6	2	573	49.5
High × High F_2*		2		3	3	7	5	5	3			28	46.8
High × Low F_2	11	49	89	116	185	170	183	92	34	7	4	940	40.5
Low × Low F_2	40	40	3	1	5	1		1	2			93	7.0

*Minnesota No. 2 × Abruzzes.

F_3 RESULTS—1932

In 1932 F_3 material was grown and selfed as follows:—

Cross	Number of lines	Average number of plants selfed per line
High × High (348–6 × 410–3)	25	16.4
High × Low (377–9 × 348–11)	25	16.6
Low × Low (338–5 × 321–2)	24	4.7

The seed used was from selfed F_2 plants. Each of the three groups descended from a single selfed F_1 plant. The small number of plants available for selfing in the Low × Low F_3 group was due to the low seed-setting of F_2 plants and to the dying of many weak plants in F_3. In each of 12 F_3 lines in the Low × Low group only one plant survived to maturity. Such a plant would be the strongest and probably the most highly self-fertile plant in a line. This would tend to raise the level of self-fertility in F_3 as compared to F_2.

The percentage seed setting of F_3 plants was determined and the mean for each line calculated. Figure 2 shows the distribution of these means. It appears that in the particular High × Low cross tested here low self-fertility cannot be inherited as a simple Mendelian character since in 25 strains there would almost certainly be some averaging below 30% for seed setting. A more complex inheritance would account for the absence of such strains. So also would selection of pollen through differential rate of pollen tube growth. The Low × Low curve shows a preponderance of low fertility strains and here again as in F_2 there are some strains with moderately high fertility. Since almost one half of the F_2 plants of the Low × Low crosses set no seed and therefore had no progeny, there has been a marked selection for self-fertility. This accounts for

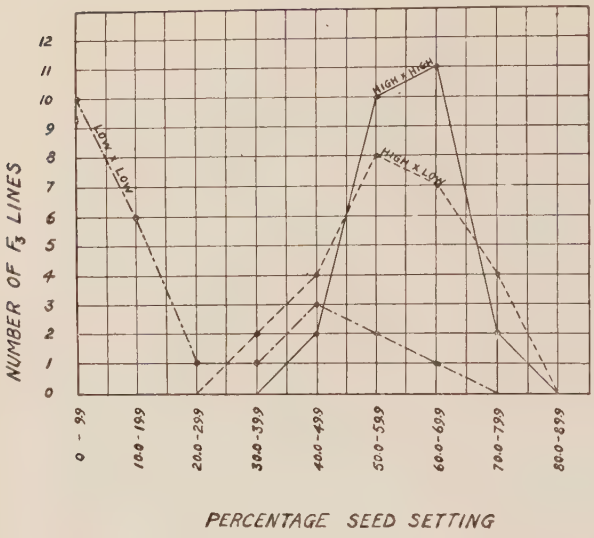

FIGURE 2. Distribution of F_3 lines for average percentage seed setting of selfed plants

the average seed setting being higher in F_3 than in F_2. The Low × Low results for F_1, F_2 and F_3 would indicate that hybrid vigour alone is not sufficient to bring about high self-fertility.

From the results of the crosses it would be expected that in rye grown under ordinary field conditions the presence of factors for low self-fertility might have some effect in lessening the seed setting since the apparent dominance of high self-fertility does not seem to be quite complete.

Correlation coefficients for the average per cent seed setting of F_3 lines in 1932 and the percentage seed setting of the F_2 parent plants in 1931 were calculated. These are as follows:—

Cross	r	t	p
High × High	+.511	2.851	Less than .01
High × Low	+.255	1.265	
Low × Low	−.016		

In the High × High cross, it is plain that the correlation coefficient for F_2 and F_3 seed setting is significant. In the High × Low cross the correlation coefficient is not significant, while in the Low × Low cross it is close to zero. It might have been expected that the most significant correlation coefficient would have been obtained from the High × Low group since the parents were here more strongly contrasted with respect to self-fertility than in the other groups. The parents in the High × High cross, however, were developed from two distinct varieties and probably differed in a large number of factors affecting self-fertility more or less. In the other crosses, the parents all came from Minnesota No. 2 rye and probably had many factors in common. This may account in part for the high correlation coefficient in the High × High cross as compared with the other groups. Since in one half of the F_3 lines of the Low × Low cross only one plant was obtained for study, one would not expect the data to be accurate enough to give a significant correlation coefficient based on a sample of only 24 lines.

It is evident that the characters of high and low self-fertility are heritable. Yet it appears that the correlation of seed setting for different

years is not as a rule very high. Brewbaker (*5*) reports "a correlation of the percentage seed setting in 1925 of 45 strains which had been selfed 3, 4, or 5 years with the percentage seed setting of the same strains for 1924 gives a correlation coefficient of 0.2044 ± 0.0963." The same writer studied data of Heribert-Nilsson (*14*) by computing a correlation coefficient for percentage seed setting of 42 strains in two consecutive years. The calculated coefficient was 0.1709 ± 0.1010. The measure of significance here used is the probable error. It is evident that these coefficients can not be regarded as significant.

THE EFFECT OF COMBINING SELECTED SELF-FERTILIZED LINES—1933

The work in 1933 consisted of a comparative study of Minnesota No. 2 rye and three "synthetic" varieties produced by combining selected self-fertilized lines of Minnesota No. 2. This was undertaken to determine whether any improvement had been attained, particularly in seed setting and kernel weight, and to determine the effect of genes for sterility or low fertility on seed setting in a population of rye grown under ordinary field conditions where open pollination takes place.

In 1931 Dr. Hayes selected 36 rye plants to be combined to produce three new rye varieties. The plants were the result of continued selfing in Minnesota No. 2 rye with selection for self-fertility, plump seed, and good general appearance in the field. The selfed seed was bulked in three groups as shown in Table 6, the three being characterized by colourless, light-green, and dark-green seed respectively. The bulked seed was sown in three space-isolated plots in the fall of 1931 for increase. This material was made available to the writer for seed setting studies.

TABLE 6.—THE ORIGIN OF THREE NEW VARIETIES PRODUCED FROM MINNESOTA NO. 2 RYE

No. of 1931 plants	Average No. of years selfed	Average % seed setting of the selected plants	Disposal
11	6	68.8	Bulked for a colourless selection to be called Minnesota No. 111
8	6	63.8	Bulked for a light-green selection to be called Minnesota No. 112
17	5	74.5	Bulked for a green selection to be called Minnesota No. 113

All the seed taken from the three plots in 1932 was from natural pollination. In 1933 a replicated test was planned. In each of three districts in Manitoba, Canada, viz. Winnipeg, Teulon and Rosser, the three synthetic varieties and the original Minnesota No. 2 rye were grown. The plots were 20 ft. × 20 ft. in size. In each district the four varieties were grown on the same field except in the case of Winnipeg where it was necessary to put variety No. 112 in a field apart from the rest. The culture of the two fields, however, had been similar. The plots were in every case at least 600 feet apart. The locations for the plots having been chosen, the varieties were assigned to them at random. The four varieties were grown at University Farm, St. Paul, primarily for increase. These plots

were not of uniform size, but approximately so, and the data from them were included in the study, making four replicates in all. One plot (No. 112) was entirely destroyed at Teulon by ice smothering. The stands in the remaining plots were satisfactory.

The percentage seed setting was obtained on a random sample of 100 heads from each of the 15 plots. Two spikelets were removed from the top and two from the bottom of each spike and the counts were made on the lateral florets of the remaining spikelets. The means for the percentage seed setting of the hundred heads in each sample are given in Table 7. The standard errors of the means given here were obtained from calculating the standard deviation of each 100-head sample separately.

TABLE 7.—MEANS AND STANDARD ERRORS FOR PERCENTAGE SEED SETTING OF 100 HEADS OF RYE IN EACH OF FOUR VARIETIES AT EACH OF FOUR LOCALITIES

——	Minn. No. 2	Minn. No. 113	Minn. No. 112	Minn. No. 111
Winnipeg	72.55 ± 1.68	77.76 ± 1.42	81.20 ± 1.30	83.31 ± 1.43
Teulon	71.25 ± 1.62	75.34 ± 1.51	(78.56)*	84.33 ± 1.15
Rosser	69.48 ± 1.66	75.40 ± 1.64	75.41 ± 1.64	77.48 ± 1.41
St. Paul	75.76 ± 1.54	73.19 ± 1.36	77.02 ± 1.74	81.72 ± 1.34
Variety means	72.76	75.42	78.05	81.71

*Estimated by Allan and Wishart's method (2).

The new varieties showed a higher seed setting than Minnesota No. 2 in all districts with one exception: Minnesota No. 113 had a lower seed setting than Minnesota No. 2 at St. Paul. The value for the missing plot at Teulon was estimated by the method of Allan and Wishart (*2*). This made it possible to use all the available data in an analysis of variance. This analysis is given in Table 8, and is of the form developed by Fisher (*12*). In this analysis "districts" corresponds to "blocks" in the ordinary

TABLE 8.—SEED SETTING ANALYSIS OF VARIANCE COMPARING THREE SYNTHETIC VARIETIES WITH MINNESOTA NO. 2 RYE

——	Sums of squares	Degrees of freedom	Variance or mean square	$\frac{1}{2}\log_e$	z	5% point	1% point
Varieties	192.6362	3	64.2121	2.0811	1.2889	0.7014	1.0135
Districts	38.0494	3	12.6831	1.2701	0.4779	0.7014	1.0135
Error	39.0190	8	4.8774	0.7922			
Total	269.7046	14					

randomized block test. There are only 8 degrees of freedom for error instead of 9, one being lost due to fitting the value for the missing plot. The approximate value of z for a comparsion of variance due to varieties and that due to error is 1.2889. The value of z at the 1% point for $n_1 = 3$ and $n_2 = 8$, given in Fisher's table (*17*) is 1.0135. So we may conclude that there were quite significant differences between varieties for seed setting. The standard error of a variety mean in this test is $\sqrt{4.8774/4}$ or 1.1042. For the mean of variety No. 112, however, for which one plot was missing, the standard error is $\sqrt{4.8774/3}$ or 1.2751. The standard error of a difference between two variety means is $\sqrt{2} \times 1.1042$ or 1.5616. When variety No. 112 is one of the two varieties being compared, the standard error of the difference would be $\sqrt{4.8774/4 + 4.8774/3}$ or 1.6868. If a difference between two variety means is 3.355 times as great as the standard error of the difference, the probability of the difference being due to chance is .01. If the difference is 2.896 times as great as the standard error the corresponding probability is .02. Hence the following varietal differences appear to be significant:—

Minn. No. 111 — Minn. No. 2	= 8.95	d/S.E. = 5.73
Minn. No. 112 — Minn. No. 2	= 5.29	d/S.E. = 3.14
Minn. No. 111 — Minn. No. 113	= 6.29	d/S.E. = 4.03

This shows that not only were there significant differences between Minnesota No. 2 rye and the synthetic varieties but also between the synthetic varieties themselves. The differences in seed setting due to districts cannot be judged to be significant in this test.

The weight per 1,000 kernels, height, and average number of spikelets per spike for the fifteen plots were determined. The first character was studied to determine the effect of selection for plump seed. The other two characters were studied in an attempt to determine whether the varieties differed in vigour. The height averages were based on ten measurements in each plot. The average number of spikelets per spike was determined from the same 100 heads per plot used to determine the per cent of seed setting. In each case the value for the missing plot was estimated by means of the method of Allan and Wishart. The mean values for all districts were as follows:—

——	Minn. No. 2	Minn. No. 113	Minn. No. 112	Minn. No. 111
1000-kernel weight (grams)	21.9	23.2	24.6	23.0
Height (inches)	45.2	44.8	49.0	49.0
No. of spikelets per spike	28.6	29.0	28.5	28.3

It is interesting that all of the synthetic varieties had a higher mean kernel weight than Minnesota No. 2. An analysis of variance showed that differences due to varieties and those due to districts were both significant. The kernel weight of variety 112 was significantly greater than that of Minnesota No. 2.

The data for height and for number of spikelets per spike were analyzed in the same way. In both cases the variance due to districts was highly significant while that due to varieties was not.

Comparative yield tests of the new varieties have not yet been made There can be little doubt, however, that a variety excelling Minnesota No. 2 in both kernel-weight and seed setting will also excel in yield. Whether the synthetic varieties will maintain their superiority over Minnesota No. 2 rye in later generations still remains to be determined.

Discussion

It has already been shown by various studies that factors for different degrees of self-fertility and self-sterility can be isolated in rye by means of self-pollination. From the results of the crosses here reported it appears that, in some cases at any rate, strains of very low self-fertility may be highly fertile when crossed with other strains of low self-fertility but that the progeny of the cross will be of low self-fertility like the parental strains. In a population made up of a mixture of strains of low self-fertility with open pollination taking place year after year the obligatory cross-fertilization would insure a fairly high degree of heterozygosis, an advantage from the standpoint of survival. But if the wind pollination is not mechanically perfect some florets will not be fertilized. When different strains of high self-fertility are crossed not only is the cross fertile but the progeny are self-fertile. In populations of highly self-fertile plants the degree of heterozygosis would tend to be less than in the previous case due to self-pollination. However, many florets that received no foreign pollen would yet set seed through self-pollination, an obvious advantage. Strains of high self-fertility, crossed with others of low self-fertility give results very similar to those of the High $\times$High crosses, but the self-fertility of the progeny is somewhat lower.

The improved seed setting of the synthetic strains as compared with Minnesota No. 2 rye is no doubt due in part to high self-fertility making possible the self-fertilization of florets which received no foreign pollen and would otherwise have set no seed. If hybrid vigour plays an important part in the degree of seed setting, part of the improvement may be lost in later generations of this material, as self-pollination lowers the degree of heterozygosis.

In actual practice full advantage could be taken of both hybrid vigour and selection of genes for self-fertility, seed size, etc., if the farmer grew as a commercial crop a hybrid population from seed produced by growing a mixture of a few carefully selected pure lines. These lines should be alike for such obvious characters as seed colour and should be selected for high fertility and large kernels. It would be necessary to grow each year small isolated plots of the pure lines and also one plot of a mixture of the lines of sufficient size to produce seed for the commercial crop the following year. A few pure lines selected from a single variety would be satisfactory material as shown in this study.

The work reported here was carried on from the standpoint of a plant breeding program and the detailed genetic studies necessary for determining the basis of sterility in rye were not carried out. The data obtained, however, give some indications of the nature of sterility in rye. In the study of the basis of sterility in plants, two main hypotheses have been useful, that of selective pollen tube growth and that of gametic sterility. The former, advanced by East and Mangelsdorf (*10*) with supporting

evidence from genetic studies in *Nicotiana* is summarized briefly by East (*8*) as follows:—

"There is an allelomorphic series of genes of such a nature that pollen tubes having a given sterility gene grow slowly in style tissue having the same sterility gene in its constitution and rapidly in style tissue having a different sterility gene in its constitution. The ordinary result of these varying rates of pollen tube growth is that a plant of constitution S_1S_2 cannot be fertilized by its own pollen or by pollen from any other source bearing either of these sterility factors; but can be fertilized by pollen bearing a different sterility factor, such as S_3."

Thus such crosses as $S_1S_1 \times S_2S_2$, $S_1S_2 \times S_1S_3$ or $S_1S_2 \times S_3S_4$, where both parents are self-sterile but differ by at least one S factor, would be fertile but the F_1 plants would be self-sterile like the parents.

The results of the rye studies here reported agree, as far as they go, with this hypothesis. The sterility in rye, however, is not so complete as in *Nicotiana*. In this paper the terms high and low self-fertility have been used. The strains of very low self-fertility might be said to have a high degree of self-sterility. The two crosses between plants of low self-fertility, viz., 338–5 × 321–2 and 325–9 × 321–2, were fertile, but the selfed F_1 plants were similar to the parents in having low self-fertility. These results could be explained by the presence of allelomorphic factors similar to those of the S series in *Nicotiana*. It is apparent that on this basis culture 321 must differ from both 338 and 325 by at least one sterility factor.

If the allelomorphic S factors were the only factors differentiating the degree of sterility in the Low × Low crosses, the F_2 and F_3 selfed plants would be expected to be highly as self-sterile as the F_1. But since a few fertile plants appeared in F_2 and still more in F_3 it would appear that subsidiary factors affecting fertility may have been present. Selfing would bring about a rigid selection in favour of such factors. These fertile plants, however, possibly arose through cross-pollination in F_1.

East and Yarnell (*11*) reported the finding of a fertility factor S_f belonging to the S series of allelomorphs in *Nicotiana*. It has been shown since by East and his co-workers that this factor evokes rapid pollen-tube growth in all combinations. When plants homozygous for known self-sterility factors were crossed with plants homozygous for the S_f factor (*9*) the F_1 plants S_fS_n were self-fertile. These were sterile to S_n pollen but fertile to S_f pollen and consequently the selfed F_1 plants yielded F_2 populations consisting of equal numbers of plants belonging to the two classes S_fS_f and S_fS_n, both being self-fertile. The fact that the F_1, F_2 and F_3 plants from the High × High and High × Low crosses of rye here reported were as highly self-fertile as the parents of high self-fertility points to an explanation of self-fertility in rye similar to that proven for *Nicotiana*.

Although the High × High and High × Low crosses gave very similar results, the F_1, F_2 and F_3 progenies of the latter seem to be somewhat lower in self-fertility than those of the former. There are several plausible explanations. S_fS_n (High × Low F_1) plants may not be as fully self-fertile as S_fS_f (High × High F_1) plants, at any rate only one half of the pollen of the former group would behave normally in self-pollination. Also since the self-sterility dealt with here is not complete, a few seeds not bearing

the S_f factor might be formed on S_fS_n plants through fertilization by S_n pollen. These would give rise to plants of low self-fertility in later generations. It is possible that the low self-fertility of the one parent was due in part to subsidiary factors for gametic incompatibility. The effect of these would appear in F_1, F_2 and F_3.

Summary

A study was made of the use of self-fertilized lines in rye breeding with special reference to the increase of seed setting and seed size. With the exception of one strain from the variety Abruzzes, the material used originated from a bulk selection of Swedish rye known as Minnesota No. 2.

Self-pollination in the same year of various strains that had been selfed for different numbers of generations with selection for self-fertility showed that there was a progressive increase in self-fertility for several generations and that from the seventh generation onward the average percentage seed setting of the strains remained in general fairly uniform.

Strains selfed for a number of years and showing different degrees of self-fertility were crossed. F_1, F_2, and F_3 progeny were selfed. The progeny of crosses between highly self-fertile strains showed a higher average per cent seed setting in F_1, F_2, and F_3 than the parents. Similar results were obtained when strains of high self-fertility were crossed with strains of low self-fertility, but in general the seed setting was slightly lower and there was more variability.

In crosses between strains of low self-fertility the progeny were for the most part like the parents. A small proportion of the plants in F_2 were rather highly self-fertile. This proportion increased somewhat in F_3 due to the survival of the self-fertile plants and the loss of many self-sterile and weak plants in F_2.

There is an apparent dominance of high self-fertility over low self-fertility crosses, but the results might be better explained on the basis of selective pollen tube growth.

Seed from the selfed F_2 plants of High $\times$ High and High $\times$ Low self-fertility strains was plumper and had greater germinating ability than seed from the F_2 of Low $\times$ Low self-fertility strains.

Self-fertilized lines of Minnesota No. 2 rye having high self-fertility were combined to make three "synthetic" varieties. The three "hybrid" populations from these mixtures were compared with Minnesota No. 2 rye in four replicates each in a different district. All three synthetic varieties had a higher average seed setting and 1,000-kernel weight than Minnesota No. 2 rye. Using Fisher's analysis of variance, it was shown that two of the synthetic varieties had a significantly higher percentage seed setting than Minnesota No. 2 rye and the third synthetic variety. One of the new varieties had a significantly higher kernel weight than Minnesota No. 2.

No significant differences between varieties for height or for number of spikelets per spike were established.

It will be necessary to test later generations of this material to determine how much of the improvement will be permanent in successive generations with open pollination.

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RÉSUMÉ

L'AMÉLIORATION DU SEIGLE PAR LA REPRODUCTION EN CONSANGUINITÉ. R. F. Peterson, Laboratoire fédéral de recherches sur la rouille, Winnipeg, Man.

Cette étude portait sur l'emploi d'espèces auto-fécondées dans la multiplication du seigle. Elle se rapportait principalement à la formation de la graine et à la grosseur de la graine. A l'exception des espèces de la variété des Abruzzes, tous les matériaux employés provenaient d'une sélection en masse de seigle suédois appelée Minnesota No. 2. L'auto-pollinisation effectuée pendant la même année, de différentes espèces qui avaient été pollinisées pendant différent nombre de générations en vue d'accroître l'auto-fécondité, a fait voir qu'une augmentation progressive d'auto-fécondité se produit pendant plusieurs générations et qu'à partir de la septième génération le pourcentage moyen de semences formées sur les différentes espèces reste en général assez uniforme. On a croisé entre elles des espèces qui avaient été auto-fécondées pendant un certain nombre d'années et qui présentaient différents degrés d'auto-fécondité. La progéniture de F_1, F_2 et F_3 a été auto-fécondée. La progéniture des croisements entre les espèces hautement auto-fertiles a révélé une proportion moyenne plus forte de formation de semences dans F_1, F_2 et F_3 que dans les parents. On a obtenu les mêmes résultats lorsque des espèces de forte auto-fertilité étaient croisées avec des espèces de faible auto-fertilité, mais en général la quantité de semences formée était un peu plus faible et il y avait plus de variations. Dans les croisements entre les espèces à faible auto-fertilité, la plupart des sujets de la progéniture étaient comme leurs parents. Une petite proportion des plants dans F_2 étaient plutôt hautement auto-fertiles. Cette proportion a quelque peu augmenté dans F_3 à cause de la survivance des plants auto-fertiles et de la perte de nombreux plants faibles et auto-stériles dans F_2. Les croisements à forte auto-fertilité paraissent dominer sur ceux à faible auto-fertilité, mais les résultats s'expliquent peut-être mieux sur la base de la végétation sélective du tube du pollen. La semence provenant des plantes auto-fécondées F_2 des espèces Forte x Forte et Forte x Faible auto-fécondées, était mieux nourrie et avait une faculté germinative plus forte que la semence issue des espèces F_2 à auto-fécondation Faible x Faible. On a combiné les lignes auto-fécondées du seigle Minnesota No. 2 ayant une haute auto-fertilité, pour obtenir trois variétés synthétiques. Les trois populations hybrides issues de ces mélanges ont été comparées avec le seigle Minnesota No. 2 en quatre replicatas, chacun dans un district différent. Toutes ces trois variétés synthétiques avaient une plus haute moyenne de formation de semence et un poids plus élevé par 1,000 grains que le seigle Minnesota No. 2. Si l'on emploie l'analyse des variations de Fisher, on voit que deux des variétés synthétiques avaient un pourcentage de formation de semences beaucoup plus élevé que le seigle Minnesota No. 2 et la troisième variété synthétique. Une des nouvelles variétés avait un poids par boisseau beaucoup plus élevé que le Minnesota No. 2. Il n'a pas été établi de différences significatives entre les variétés pour la hauteur ou le nombre d'épillets par épi. Il sera nécessaire d'étudier les dernières générations de ces matériaux pour voir quelle proportion de cette amélioration sera permanente dans les générations successives, à pollinisation libre.

AN ACCOUNT OF THE EASTERN HEMLOCK LOOPER, *ELLOPIA FISCELLARIA* Gn., ON BALSAM FIR

E. B. Watson[1]

Dominion Entomological Branch, Ottawa, Canada.

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Introduction

The hemlock looper is a comparative newcomer to the ranks of pulpwood pests in Eastern Canada, though it has been known for some years to be destructive to balsam in Newfoundland. As the popular name suggests, the insect is partial to the hemlock (*Tsuga canadensis*), and numerous outbreaks of the insect have occurred in hemlock forests in Ontario and in the Lake States; in some of these outbreaks, notably in Wisconsin and Michigan, the balsam as well as other coniferous and deciduous trees have been affected, though hemlock seems to be preferred to all other food-plants wherever it is available.

The hemlock looper is native to North America. It is widely distributed, the range extending from the Atlantic to the mid-western states; in Canada it is known to occur from Manitoba eastwards.

Outbreaks in Quebec and Nova Scotia

Previous to 1928, the insect was unknown as a pulpwood pest in Canada; since that date, however, several outbreaks on balsam fir have been known to occur, all in the province of Quebec. In the year 1928, on the North Shore of the Gulf of St. Lawrence, outbreaks appeared in a number of localities from Pentecost to Bersimis, involving about one million cords of balsam. In the same year a small, localized outbreak occurred on the Wesseneau river, in the St. Maurice valley. In 1930, the Dominion Forest Service reported a flight of moths in the vicinity of Mitchinamekus Lake, on the headwaters of the Lièvre river and an unconfirmed report indicated that caterpillars were numerous near Chibougamau, north of the Transcontinental Railway. Moths were also reported to be abundant and widely distributed in the counties of Richmond and Guysborough in Nova Scotia.

The outbreak on the North Shore was the only one which could be considered to have reached decidedly serious proportions; this region supports some of the finest stands of pulpwood in the province of Quebec and previous to 1928 had been apparently immune from serious insect outbreaks. The district had not been affected by the spruce budworm, which in 1910 and succeeding years ravaged the Saguenay and South Shore districts and which later swept through New Brunswick. The North Shore outbreak, developing as it did in highly valuable stands of balsam, was naturally viewed with anxiety, since a considerable amount of timber had been killed in one year and there was every indication that the outbreak would continue in virulence for several years to come.

[1] Assistant Entomologist.

Bionomics

Biological studies on the hemlock looper were initiated on the North Shore in 1929 and continued in 1930; while the study of the infestation was commenced primarily with a view to determining the bionomics of the insect, the course of investigations covered also the possibilities of artificial control by means of aerial dusting and properly conducted logging operations.

General appearance of an outbreak

In general appearance, an outbreak of the hemlock looper in a balsam forest bears a close resemblance to a spruce budworm infestation; there are, however, certain differences. In the case of the looper outbreak on the North Shore, the defoliated areas were very irregularly distributed; for example, an area of balsam of ten or twenty acres might be completely defoliated and an adjacent area of the same type might be practically untouched. In a budworm outbreak, the infestation is generally much more evenly distributed over the whole district, almost every balsam showing some visible signs of feeding.

Outbreaks of the hemlock looper develop with extraordinary rapidity; almost without warning, enormous numbers of caterpillars appear, which under favourable circumstances, will completely strip the balsam of all sizes from young trees two or three feet in height to mature timber. This feeding will often result in the death of the stand within the year. The reproduction is often more severely injured than the larger trees; it is a common occurrence for trees from six to thirty feet in height to be killed, the smaller reproduction and merchantable timber being left living. Sometimes the second growth alone is affected, the young trees up to ten feet in height showing unmistakeable signs of feeding while the mature trees are apparently uninjured. This condition is more likely to occur in the early stages of an outbreak or in cases where the insect is present in small numbers but has not become epidemic.

Undoubtedly much of the injury to the tree is caused by wasteful feeding; the caterpillars do not, apparently, commence feeding on a leaf ane consume it entirely before passing on to the next leaf. In a heavily infested tree, almost every leaf will show signs of having been nibbled. Very often the feeding takes place at the extreme base of the needle, so that the leaf soon dies and becomes red in colour; this accounts for the characteristic red appearance of an infested forest, especially in the month of August; a closer examination reveals the presence of thousands of dead leaves, their bases gnawed off and remaining attached to the twigs by numerous strands of silk spun by the caterpillars. These festoons of dead and half eaten needles hanging from the twigs are very characteristic of an outbreak of the hemlock looper. Later in the fall, the dead leaves are removed to some extent by wind, rain and snow and the red appearance of the forest largely disappears.

Life-history and habits

The life-history of the hemlock looper is simple; the insect is single-brooded, the moths appearing in late August or in September and laying their eggs in the latter month. The eggs do not hatch until the following

Figs. 1 and 2—Balsam defoliated by the hemlock looper.

June, when the caterpillars are to be seen feeding on the leaves of their host-tree. Pupation occurs in early August, the moths appearing about two or three weeks later.

The eggs, which are deposited singly or in small groups of two or three, may be found almost anywhere; they have been found on the twigs of balsam, usually in the mass of silk and dead leaves left as a result of the feeding of the caterpillars. The female moths appear to show a preference for sites having some crack or crevice wherein to deposit their eggs; old cones are sometimes utilized, and trunks of trees, in crevices of the bark. The most favoured site for eggs appears to be in dry and decayed stumps and stubs; these are also the favourite places selected by the caterpillars for pupation. Eggs were to be found, often in numbers, in cracks and crevices of old spruce stumps which had been cut about thirty years before on one of the infested limits. This habit of egg-laying in old stumps probably explains why the young caterpillars in June and early July are to be found so abundantly on the reproduction.

The young larvae, on hatching, feed openly on the new foliage of the balsam and even on the small trees, there is a distinct tendency to congregate around the terminal shoot; as the caterpillars increase in size, they commence to ascend the larger trees; apparently they cannot recognize the favoured host-tree, as numbers of young caterpillars have been observed climbing up trees which had been dead for a number of years, as well as living spruce and birch. Although caterpillars are to be found feeding on the foliage at all levels, there is no doubt that they occur more abundantly in the upper branches; it might be said that 90% of the caterpillars on a balsam are to be found on the upper fifth of the tree. As the majority of the eggs are laid on sites near the ground, it is obvious that the reproduction suffers most from the early feeding; since the small trees and saplings almost invariably outnumber the mature timber, it can readily be seen that the caterpillars are more abundant on the smaller trees than on the mature timber.

The feeding of the caterpillars on the reproduction is generally only a temporary condition, as they always exhibit a tendency to climb the large trees. Mature caterpillars are to be found throughout the feeding period on the small tress but it is probable that they have become dislodged from other trees and have just settled on the reproduction prior to ascending the larger trees once more.

As a result of the wandering habits and restlessness of the caterpillars, it is difficult to estimate the population in a given area; experiments carried out in the spring of 1930 when the outbreak was decidedly on the decline, indicated an average population of over one million to the acre. This figure was arrived at by counting first stage caterpillars in a number of plots each ten feet square. Some of the plots contained old and decayed stumps and since these are the most popular sites for oviposition, the number of caterpillars taken from these plots was considerably in excess of the number from plots where these stumps were absent. One old stump about five feet in height yielded nearly three thousand caterpillars; many more probably had left the stump in search of food and others may have been overlooked.

In the North Shore outbreak, the favoured food-plant and the tree to suffer most from the ravages of the hemlock looper is the balsam fir (*Abies balsamea*). The hemlock (*Tsuga canadensis*) does not occur on the North Shore. Both white spruce and black spruce, especially the reproduction, are also fed upon, but no instances were observed in which trees of these species were totally defoliated or killed, although white spruce has been reported killed by the hemlock looper in Newfoundland. In the early stages, the caterpillars are found feeding on all kinds of small vegetation such as *Amelanchier, Acer rubrum, A. spicatum, Vaccinium* and *Cornus*. Older caterpillars are sometimes found on birch but their presence is probably only casual as these trees have not been defoliated to any appreciable extent even when situated in a heavily defoliated stand of balsam. Under cage conditions, third stage caterpillars were successfully brought to maturity on a diet of birch foliage.

It has been proved conclusively in a number of experiments that first stage caterpillars cannot subsist on the old growth of either spruce or balsam; caterpillars provided with such foliage made no attempt to feed and invariably died of starvation or else were devoured by their neighbours. Experiments carried out with a view to determining the maximum length of time first stage caterpillars can live without feeding were productive of some interesting results. In no instance were caterpillars observed to survive more than four days starvation, the majority dying on the second and third days. There is no doubt that caterpillars when caged in vials without food do not hesitate to feed upon each other. Cannibalism was evident in nearly all experiments where starvation studies were being carried out; it was also noticed when caterpillars were provided with unsuitable food-plants such as the old foliage of spruce or balsam. The table submitted below will serve to show the rate of death among caterpillars when confined in vials without food. A somewhat similar mortality rate was obtained when young caterpillars were confined with the old foliage of spruce or balsam, so that the absence of humidity in the vials containing no food-plant whatever had little or no influence on the death of the caterpillars.

TABLE 1.—LONGEVITY TESTS OF FIRST STAGE CATERPILLARS COLLECTED JUNE 18 AND CAGED IN VIALS WITHOUT FOOD. TEN CATERPILLARS PLACED IN EACH VIAL

Day of death	Number of dead caterpillars. Vial number										Total number dead
	1	2	3	4	5	6	7	8	9	10	
Second day	4	8	9	9	7	8	7	8	9	8	77
Third day	6	2	1	0	3	2	1	2	1	2	20
Fourth day	–	–	–	1	–	–	2	–	–	–	3

N.B.—
77% were dead on the second day.
97% were dead by the third day.
100% were dead by the fourth day.

In all starvation and similar experiments a separate series of caterpillars was being reared with young balsam foliage under similar conditions; these caterpillars made satisfactory progress, so that the heavy mortality

observed in other experiments could not be attributed to unsatisfactory rearing conditions. The complete mortality of hemlock looper caterpillars on the fourth day of starvation is in marked contrast to the spruce budworm; similar experiments carried out with this species showed that 50% of the caterpillars were living on the fourth day of starvation and that one remained alive for eleven days.[2] The inability of the young caterpillars to survive long periods without feeding is probably of considerable importance in the successful application of artificial control by means of clean cutting; this is discussed later.

Pupation takes place towards the end of July or in the first week of August according to season; the pupae are to be found almost everywhere; specimens have been taken quite exposed on the twigs at the tops of the trees and on the lower branches. They are often abundant in crevices of the bark, among the lichen on the trunk and often occur in numbers behind a loose piece of bark. Other sites are on the ground without any covering whatever, sometimes just below the surface litter or sheltered by a chip or leaf. The most popular resorts, however, were dry, decayed, and heavily checked stumps or stubs. The caterpillars not infrequently entered deep checks and pupated in the wood at a depth of two inches or more. If the decayed wood was inclined to be damp, the numbers of pupae to be found therein were comparatively small.

Emergence of the moths takes place generally in the month of September; the males are the first to appear, the peak emergence period of this sex being about a week in advance of the corresponding period of the females. The insects may be seen flying at all hours, though activity becomes more pronounced towards the evening. The males are attracted to light. The moths are eager for moisture and are often to be seen in numbers on patches of mud or wet sand. They also drop readily into water; when the insects are very abundant, the surfaces of lakes and rivers are often covered with their bodies.

The flight habits of the hemlock looper were studied in some detail in September 1929 in one locality where the insects were fairly plentiful. On warm days the males were to be seen flying everywhere and in every direction and there was nothing observed which might indicate that the moths were swarming from one locality to another; all the flights appeared to be aimless. Very few females were observed flying except when disturbed. The powers of flight of both sexes are apparently feeble. A noticeable feature in connection with the flight habits is that the moths seldom fly high; when at rest on the trunks of trees, they are always more abundant on the lower ten feet than on any other part, though a few moths can generally be dislodged from the upper trunk and branches by jarring the tree. The moth flight is generally over by the end of September; if the weather is not too severe, occasional specimens may be encountered up to the middle of October.

Type of forest affected

The forest in which the infestations occurred is almost wholly a balsam-spruce type; the balsam is the predominant species and occurs frequently in pure stands with occasional white spruce of large dimensions

[2] Studies on the Spruce Budworm. Bull. 37, N.S. Dom. Dept. Agr. Ottawa, 1924.

or mixed with black spruce. Towards the tops of the hills and mountains or on poor soil, the black spruce becomes more in evidence. Swampy areas are also usually of a pure black spruce type. The hardwoods are poplar and white birch; the former is usually associated with old burns and the latter is more or less evenly distributed throughout the mature forest, becoming more plentiful along the river valleys and also associated with poplar in the burns. Jack pine occurs locally in pure stands but is not very widely distributed; it seems to be more prevalent along the coast line than inland. White pine, which is scattered here and there throughout the forest, does not often reach commercial size and is frequently gnarled and twisted so as to be of little value.

It was observed that the injury on the North Shore was, on the whole, more severe in pure stands of balsam than in mixed forest; severe defoliation of balsam has occurred, however, in stands containing up to 45% of spruce, calculated on the number of trees in the stand. In the North Shore outbreak, the spruce have not been severely injured with the exception of small trees growing in heavily infested stands of balsam; the larger spruce (8″ d.b.h. and over) appear to have been untouched even when surrounded by infested balsam. Wherever the small spruce have been attacked, the injury has generally been more severe on the white spruce, (*Picea canadensis*) than the black spruce (*Picea mariana*).

Origin of outbreaks

There is as yet no positive information as to the origin of hemlock looper outbreaks such as have occurred recently; the insect is native to North America and the nature of the infestations on the North Shore suggests that the outbreaks have arisen spontaneously over a number of districts, often widely separated. There is no reason to believe that the North Shore infestation developed from one central area and then spread outwards; there is certainly nothing to suggest that the outbreak originated from a flight of moths which had somehow drifted in from some distant infested region. The simultaneous appearance of all the infested areas, often completely isolated, dispels the theory at once; it is obvious that the Pentecost outbreak cannot be connected with the infestation at Manicouagan which is 75 miles further west; between these points there are a number of other infested regions but there are also large tracts of uninfested balsam.

The irregular distribution of the infestations, appearing as they do, haphazard throughout a large area of forest of more or less uniform composition, certainly suggests very strongly that all the outbreaks are entirely independent of one another. The most interesting feature in connection with these outbreaks is that there is little, if any, spread; although enormous numbers of eggs had been laid in the fall of 1928, the year of greatest abundance, the outbreak showed a marked decline in virulence in 1929; there had been certainly no apparent spread of the insect in that year from the infested areas of 1928 to the neighbouring stands of healthy balsam in 1929. It is probable that the feeble flight of the moths helps to prevent to some extent a rapid spread from one locality to another.

Winter killing

Balsam fir completely defoliated in the summer generally die in the following winter and spring. If defoliation is not complete, the trees will generally bud out again and, if subjected to no further injury, will probably continue to live. This condition is apparent over a large section of the Trinity-Calumet-Marée infestation. The 1928 feeding, though severe, did not cause complete defoliation everywhere; many of the trees have budded out well and as the outbreak has apparently subsided, there is no reason why these trees should not continue to live, since the only serious secondary insect, *Monochamus marmorator* Ky., appears to be decidedly scarce throughout the infested district.

Loss of increment

The outbreak of the hemlock looper developed with such rapidity that there is no apparent reduction of ring growth except for the years 1929 and 1930, which can be attributed to the 1928 and 1929 feeding respectively. A number of trees heavily attacked in 1928 were examined in the fall of that year but there was no evidence of any suppression of the current years' growth; the full effect of that year's feeding was not apparent until 1929 when it was found that the 1929 ring was much reduced even in those trees which did not experience any further defoliation in that year. The growth of the spruce remained normal. An examination of a number of balsam stumps from 75 to 100 years of age failed to yield any evidence of previous outbreaks; reductions in growth were apparent on most trees, but not at identical periods.

Further studies on the ring growth were made at Pentecost and Trinity in 1930; cores were taken from infested balsam in a number of localities, and as a check, a number of cores were taken from some uninfested balsam. The annual radial growth for the last ten individual years was taken from each sample and the averages recorded as shown in Figure I.

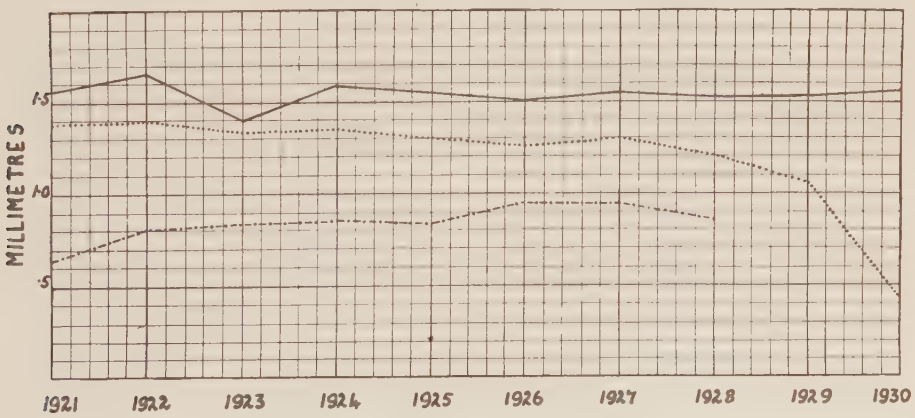

Figure 1.—Average Annual Radial Increment of Balsam

Uninfested Balsam, Pentecost Lake .....
Infested Balsam, Pentecost Lake (1928-29) .....
Balsam killed in 1928, Trinity River .....

The only marked reduction in the growth appears in the samples from Pentecost lake; the status of the outbreak in this district in 1928 was unknown, it was severe in 1929, and comparatively light in 1930. The 1930 ring in this series was, on the average, decidedly small, apparently indicative of the heavy feeding in 1929. The growth rings from the uninfested balsam, also taken from Pentecost, were remarkably uniform, varying less than one tenth of a millimetre from 1924 to 1930 inclusive. The higher average growth of this series may probably be attributed to the fact that the trees were growing on rich, alluvial soil.

The third series from the Trinity river was from trees known to have been killed in the winter 1928-1929, following heavy feeding in 1928. There is no evidence from the cores that would suggest several years of feeding previous to 1928; the growth in the year of death was as rapid as in 1921, 1920 and 1919. The comparatively slow growth of the Trinity samples is doubtless due to the fact that the trees from which the cores were taken were growing in a muskeg type, associated with black spruce.

Secondary insects

Other insects attacking the weakened and dying balsam were not as abundant as might be expected. Secondary insects have sometimes played an important part in some of the recent spruce budworm outbreaks and their presence was naturally anticipated in the North Shore infestation. The usual secondaries such as the balsam bark-beetle (*Pityokteines sparsus* Lec.) and the balsam bark-weevil (*Pissodes dubius* Rand.) were evenly distributed throughout the infested area but had not become sufficiently plentiful to threaten the recovering balsam; even on dying trees, the secondaries were far from being abundant.

Up to 1930, there were no apparent indications of any secondary insect affecting trees which were not already showing signs of impending death as manifested by a yellowing of the foliage or a discoloration of the cambium.

The balsam sawyer (*Monochamus marmorator* Ky.) appears to be decidedly scarce on the North Shore, only one specimen being observed throughout the summers of 1929 and 1930. This species although rarely seen in districts where it occurs quite commonly, breeds exclusively in balsam and has caused considerable injury in some parts of the country by killing off the recovering balsam some years after the subsidence of spruce budworm outbreaks. All *Monochamus* larvae removed from dying balsam on the North Shore proved to be those of an allied species, *M. scutellatus* Say, the well-known black sawyer beetle.

Since the spruce have not been affected at all, the swarms of bark-beetles usually associated with these trees need not be taken into consideration.

Control

Natural Control.—The North Shore outbreak caused greatest injury in the year 1928; in the following year (1929) it had practically subsided with the exception of a few areas at Pentecost; even there the degree of injury was considerably less than that sustained in 1928. By 1930, the outbreaks had subsided almost completely and all that was left to indicate

the infestation were the dead and dying balsam which had suffered severe injury in the previous years. The cause of the decline is not yet apparent. There is no evidence that the factors of starvation, parasites, disease, predatory birds or insects, had any influence whatever in reducing the numbers of the insect to what is virtually its normal state of abundance. It seems highly probable that the sudden decline can be attributed to the abnormally wet summers of 1929 and 1930. There is not much evidence in support of this theory beyond the fact that the summer of greatest abundance (1928) was both hot and dry, and that the succeding years were decidedly wet. In the course of experiments with young caterpillars, it was observed that a slight condensation of moisture in the breeding cages resulted in the death of a large percentage of the number of the occupants.

Artificial Control.—There are two methods of artificial control which may be considered feasible; the first is aerial dusting with calcium arsenate or other suitable stomach poison. This method has been proved satisfactory over small, isolated areas where the comparatively high cost has been justified not only in the value of the timber that has been saved, but also taking into consideration the prevention of possible spread over a much larger area. Aerial dusting cannot yet be considered practical in dealing with infestations which may cover large areas of fifty square miles or more. Although aerial dusting has been proved satisfactory against the hemlock looper, there is undoubtedly a great element of chance in its successful application; unsatisfactory weather conditions at the time of dusting or heavy rains immediately after the dust has been applied, and the danger of accidents are important factors that must be taken into consideration when a dusting project on a commercial scale is undertaken.

The alternative method of artificial control is the logging of the infested district. By a system of clean-cutting, the advantages are twofold. Firstly, the dead and dying merchantable balsam are at once utilized before decay sets in which would render the wood unfit for pulping purposes; secondly, a clean-cutting operation involving the removal of all balsam four inches on the stump and over, would cause the probable destruction, through starvation, of enormous numbers of caterpillars in the following spring. A clean-cutting operation on the lines described above would not leave much timber standing except the birch and the small reproduction. It has been proved in the course of the biological studies outlined in a previous paragraph, that the young caterpillars on hatching from the eggs in the spring cannot live for more than four days without food; that being the case, the caterpillars would have to subsist on the limited amount of new foliage on the reproduction or else migrate to an uncut area. While no actual figures are available on this subject, it would appear highly improbable that the reproduction left after a clean-cutting operation could sustain the caterpillars especially when they are very abundant. It is also difficult to imagine swarms of caterpillars about one sixteenth of an inch in length travelling over acres of slash into fresh feeding grounds. The old foliage remaining attached to the branches and tops of the felled trees would not serve as a temporary food-plant, as experiments have shown that the young caterpillars will not feed on the old foliage of either spruce or balsam. It is unlikely, therefore, that there

would be sufficient food left to bring the caterpillars to maturity, unless the reproduction left after logging were exceptionally thick.

As a control measure, the cutting method has its disadvantages; obviously it cannot be adopted on unleased Crown lands; even on leased limits, the facilities for handling large quantities of wood at very short notice may be inadequate or even totally absent.

RÉSUMÉ

Un compte rendu de l'arpenteuse de la pruche de l'Est, *Ellopia Fiscellaria* Gn., sur le sapin baumier. E. B. Watson, Division Fédérale de l'Entomologie, Ottawa, Ont.

L'arpenteuse de la pruche (Hemlock looper) s'est montrée un fléau destructeur du sapin baumier dans le Québec en ces dernières années. Des invasions de cet insecte se sont produites en 1928 sur la rive nord du Golfe St-Laurent. Ce sont les chenilles qui causent les dégâts; elles se nourrissent des feuilles du sapin baumier; les arbres meurent souvent au bout d'une année de défeuillaison. Les œufs sont pondus par les papillons femelles en septembre mais ils n'éclosent qu'en juin de l'année suivante. Les larves se nourrissent en juillet, elles se transforment en chrysalides en août et les papillons apparaissent bientôt après. Les moyens répressifs recommandés sont le saupoudrage par aéroplane avec l'arséniate de calcium et l'enlèvement des débris après l'abatage des arbres. Ce dernier moyen doit être préféré, car le bois mort est utilisé immédiatement avant que les détériorations se manifestent; de même les chenilles qui éclosent au printemps ne trouvent plus d'arbres sur lesquels elles peuvent se nourrir et meurent de faim.

OBSERVATIONS ON THE BROWN HEART DISEASE OF TURNIPS[1]

R. R. Hurst[2]

Dominion Laboratory of Plant Pathology, Charlottetown, P. E. I.

Introduction

Turnip brown heart, although known to the farming industry, was not thought to be economically important in Prince Edward Island. About 1928 this disorder occasioned considerable financial loss to the farmers throughout the province, many car loads of turnips being useless, while in the spring of 1929 it was a common sight to see fields of affected turnips which had been abandoned the previous year. Subsequently it was learned that brown heart constitutes a problem of major importance, as shipping point rejections are estimated to exceed an annual value of $50,000.

The few references in the literature available to the writer indicate that brown heart has not received the attention which its present importance would seem to justify. In Canada it was first mentioned in 1910, by the Dominion Botanist (1) who referred to it before the Select Standing Committee on Agriculture and Colonization. In 1913 Woods (2) of Maine investigated what appears to have been the same disorder which he mentions under the name of "Black heart."

The Name

Brown heart of turnips has been frequently referred to as water core, black heart, water heart, punky core, and woody centre. These names, however, are sufficiently descriptive to identify the condition referred to, for the symptoms suggesting the various terms are present in affected turnips at one time or another to a greater or less degree. The name brown heart, which seems quite appropriate, originated among the farmers of Prince Edward Island where it has become established.

Symptoms

Brown heart may be found in turnips ranging in size from seedlings to large roots. The only method known to the author of detecting its presence is to cut into the turnip. Some observers have stated that roots affected by this disorder exhibit a cracking of the tissues in the region of the neck; others express the belief that "long neck" in turnips is an indication of brown heart. Neither of these conclusions has been supported by our observations. Brown heart does not increase in storage, but turnips badly affected by brown heart are found to be lighter in weight as compared with sound ones after a storage period of several weeks.

On making a transverse cut through an affected turnip, (Figure 1) brown heart is readily recognized as a clearly defined brownish and mottled central area, which shows up in sharp contrast with the lighter coloured

[1] Contribution from the Division of Botany, Experimental Farms Branch, Dominion Department of Agriculture, Ottawa, Canada. Presented at the meeting of the Canadian Phytopathological Society held in connection with the World's Grain Exhibition and Conference, Regina, Canada, July 25, 1934.

[2] Plant Pathologist in charge.

surrounding tissues, but which does not extend outwards past the layer of cambium. The freshly cut surface of these turnips appears glassy, or watersoaked, (Figure 2) which has given rise to the name of "water core" for the disorder. In transverse sections turnip brown heart may be further recognized by the very frequent occurrence of concentric light and dark rings and when exposed to the air the darker portions rapidly become sunken while the lighter (normal) tissue retains its firm texture. When cut longitudinally (Figure 3) the affected area is shown to follow the fibrous tissue and to converge towards the base of the turnip.

Brown heart when present, most commonly affects one-half to three-quarters of the turnip, but in large specimens an affected area not more than one inch in diameter is frequently found. As turnips advance in age (in storage) the brownish character generally becomes less pronounced and the mottling may disappear entirely, leaving a greyish brown, dry, punky mass composed of dried out and broken down cellular tissue (Figure 4).

The palatability of brown heart turnips has been tested, and it can be stated definitely that either raw or cooked they are decidedly bitter to the taste. This observation applies only to the discoloured tissues. In addition, affected turnips when cooked are found to be distinctly woody.

Cause

There is nothing to suggest that brown heart is of parasitic origin. Nevertheless many attempts have been made in the laboratory to isolate a pathogenic organism from the affected tissue. Failure in this respect led to the conclusion that it is entirely of a physiological nature. This view was substantiated by observations in the field and further supported by opinions expressed in correspondence.

Pursuing the possibilty of virus infection a number of tests were conducted as follows:

Rubbing.—Tissue from affected turnips was rubbed on (a) the leaves (b) the scarified surface of the roots of sound turnips. All the plants were grown under insect-proof cages and upon examination at the end of the growing season showed no indication of brown heart.

Filtered juice from affected areas.—On August 8, 1931 the undiluted filtered juice from affected turnips was injected into turnips which were grown under insect-proof cages, the inoculated plants being examined October 1st. There was no evidence of brown heart in the inoculated turnips. Referring to the possible virus nature of brown heart Mr. D. J. MacLeod, Plant Pathologist at Fredericton reports as follows: "In so far as the work on the virus nature of brown heart is concerned we have not been able to establish, either from tests conducted last winter or this summer, any evidence of brown heart being due to a virus."

Investigational Work

Distribution

The occurrence of brown heart has been reported* in Denmark, England, Ireland, the United States (Massachusetts and Maine), and Canada (British Columbia, Ontario, Quebec, Nova Scotia, New Brunswick, and Prince Edward Island). It would seem, therefore, that the trouble

*Information gathered largely through correspondence.

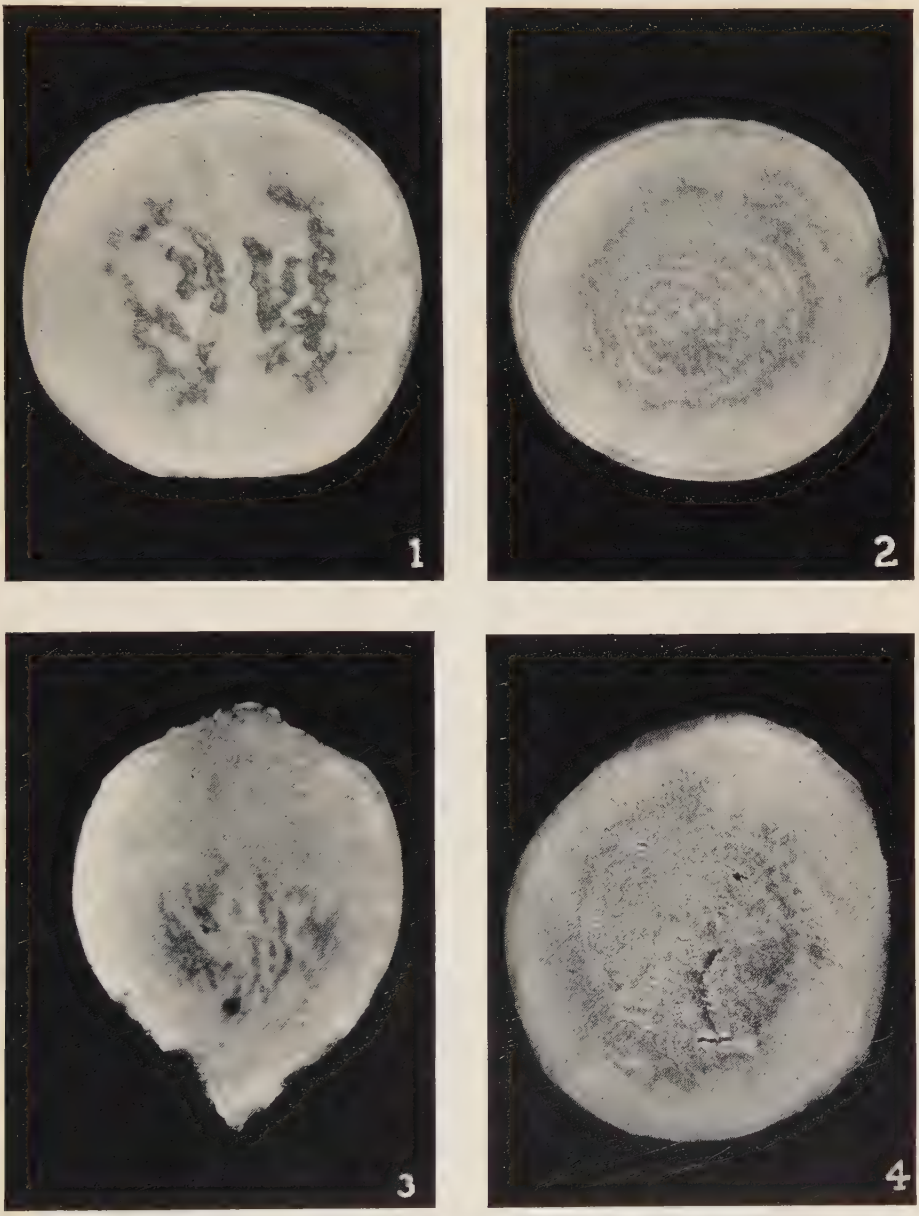

Figure 1. Brown heart of turnips. This section was cut across the lower end of a large turnip.
Figure 2. Brown heart of turnips. Note the water-soaked appearance and clearly defined light and dark concentric rings.
Figure 3. Brown heart of turnips showing the nature of symptons in a turnip cut longitudinally.
Figure 4. Brown heart of turnips showing advanced stage.

is very widely distributed. Furthermore, it has been known to be troublesome for many years in Canada and Europe. Writing in this connection from British Columbia one correspondent stated—"For over 20 years the Swedish turnips that I have grown have been affected every year with this trouble in varied degrees so that I could never be sure of having more than 50% that I could ship to Vancouver for table use with certainty that they were free from this internal trouble."

While widely distributed in Prince Edward Island its occurrence has not been reported from the farming country designated as the "North Shore", which extends from North Point to East Point. Similarly, it is uncommon in the extreme westerly section of the province where three cases only have been recorded. In the rest of the provinces, it appears sporadically, cropping up here and there, and, what is more striking, in spots or stretches in a field of turnips otherwise free from brown heart. These findings have been established by a province-wide survey conducted during the past two years (Figure 5).

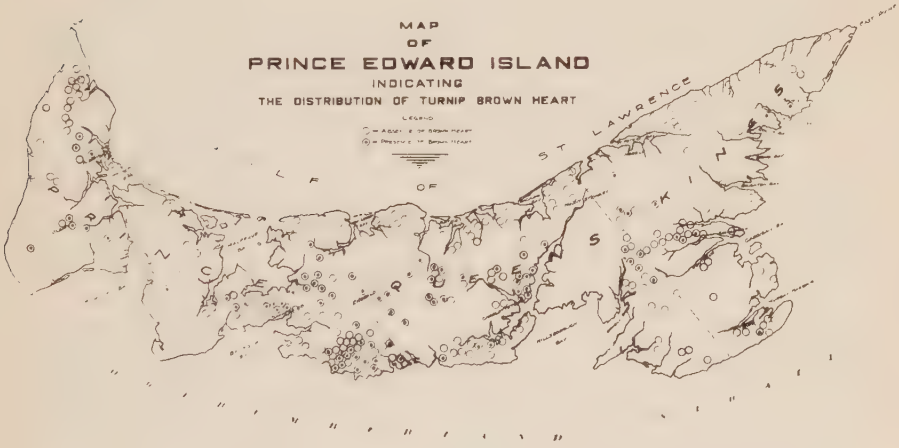

Figure 5

Varietal susceptibility

In 1931 varietal reaction to turnip brown heart was studied at Experimental Stations located as follows: Charlottetown, P.E.I.; Kentville and Nappan, N.S.; Cap Rouge and Lennoxville, Que.; and Rosthern, Sask. The varieties represented included all those offered for sale in Canada besides numerous strains and varieties secured from shipments in the spring of 1931. The data gathered from this source failed to reveal any varieties possessing immunity to brown heart, but it was noticeable that certain ones were more severely attacked than were others.

In 1932 the experiments were continued at Charlottetown with interesting and possibly important results for, out of twenty varieties

tested, absolute freedom from brown heart was exhibited by four strains of turnips namely:

Metts Bangholm (Godfrey).
Halls Westbury (Ewing).
Good Luck (Steele Briggs).
Carters Purple Top Swede.

The experimental plan giving rise to this observation comprised four widely separated replications of each of the twenty varieties represented, all of which were attacked by brown heart with the four exceptions noted above. Woods (2) expressed the opinion that strains exhibit differences in susceptibility to the trouble, basing his belief on the evidence that one variety grown under test was entirely free from what he termed, "black hearted" roots. The four varieties grown by him were: Carters Imperial, Skiwings Purple Top, White Egg, and Golden Neckless. The last named was the one entirely free from the trouble.

Effect of manure on brown heart

In the course of routine observations it was discovered that turnips were free from brown heart when grown on the former sites of manure piles. This observation was tested experimentally in 1932. In a section

Table 1.—Effect of manure on brown heart, in a field trial in 1932

Row number	Turnips on site of manure pile			Turnips not on site of manure pile		
	Number affected with brown heart	Total number turnips	Percentage affected with brown heart	Number affected with brown heart	Total number turnips	Percentage affected with brown heart
1	1	10	10.0	6	88	6.8
2	3	9	33.0	17	97	17.5
3	0	7	0.0	21	89	23.6
4	0	9	0.0	23	88	26.1
5	0	11	0.0	17	94	18.1
6	0	9	0.0	13	93	14.0
7	0	11	0.0	11	94	11.7
8	0	12	0.0	18	97	18.5
9	0	11	0.0	24	95	25.3
10	1	12	8.3	28	95	29.5
11	1	11	9.1	21	96	21.9
12	0	11	0.0	11	93	11.8
13	1	12	8.3	25	94	26.6
14	1	50	2.0	12	51	23.5
15	1	50	2.0	19	49	38.8
16	0	53	0.0	25	48	52.1
17	1	55	1.8	24	51	47.0
18	0	55	0.0	27	54	50.0
19	0	51	0.0	28	54	51.8
20	2	55	3.6	34	54	63.0
21	2	53	3.8	29	51	56.9
22	1	10	10.0	30	92	32.6
23	0	7	1.0	32	94	34.0
24	1	10	10.0	31	99	31.3
25	0	10	0.0	9	99	9.1
Total	16	594	2.6	535	2,009	26.6

of land approximately three-quarters of an acre in area, two manure heaps were placed, one in 1930, the other in 1931. Each heap occupied a space 70 feet long by 25 feet wide, both intersecting to form a right angle. The former was removed in the spring of 1931, the latter in 1932, when the entire plot was seeded to turnips in rows 30 inches apart. This particular field had received no commercial fertilizer for many years and in 1929 produced a crop of turnips badly affected with brown heart. When recording results at the end of the growing season, every turnip in the entire plot was examined critically for evidence of brown heart.

By consulting Table 1 it will be seen that brown heart was consistently absent where the rows crossed the former sites of the two manure heaps.

Effect of varying amounts of manure on brown heart

An extensive survey of the turnip fields throughout the province in 1932 yielded data confirming our previous findings that in general the amount of brown heart decreased as the applications of manure were increased regardless of variations in the quantities and kinds of fertilizers used. In the entire absence of manure, brown heart was usually present in amounts ranging from 25 to 90 per cent, a distinction which has found practical significance on those dairy farms which have been favoured for many years by the availability of barnyard manure in abundance.

The effect of different amounts of manure was studied further in a series of pot tests using well rotted manure at nine different rates, as shown in Table 2.

Ten pots were filled with each mixture, the seeds were sown on June 10th, and on November 1st each turnip was examined for indications of brown heart. The results are given in Table 2.

Table 2.—The effect of different amounts of manure on brown heart when the manure is added to a soil known to have produced affected turnips the previous year

Rate of application Tons per acre	Number of brown heart Turnips	Per cent brown heart turnips
Check (no manure).	2/10*	20.0
5	1/10	10.0
10	2/8	25.0
15	0/10	0.0
20	2/10	20.0
25	1/10	10.0
30	0/10	0.0
35	0/10	0.0
40	0/10	0.0

* The denominator indicates number of turnips examined.

Date of seeding in relation to brown heart

It has been intimated repeatedly that seeding dates have a direct bearing upon the development of brown heart, a theory discussed pro-

minently by farmers, some of whom claim that early seeding is the predisposing factor. In 1931, field observations substantiated this view in a measure, yet the irregularity of actual findings indicated the existence of certain unknown influences operating to induce brown heart regardless of the seeding dates.

When this supposition was tested experimentally, brown heart was found to be most abundant in the later seedings. This phase was subjected to a very careful study in 1932, using five different varieties with each represented by six seeding dates as follows: June 9th, June 19th, July 5th, July 15th, July 25th and August 5th. The results of the experiment are given in Table 3.

TABLE 3.—DATE OF SEEDING IN RELATION TO BROWN HEART
(Examinations completed November 5, 1932)

Seeding date	Variety					Total number brown heart turnips
	Bang-holm	Haszards improved	Mill-Pond	Grey-stone	Mammoth	
June 9	2/52*	0/35	3/39	0/18	0/30	5
June 19	1/63	3/35	1/34	1/12	1/23	7
July 5	2/44	2/130	0/46	0/59	1/63	5
July 15	1/79	1/170	0/71	0/43	1/51	3
July 25	1/56	2/137	0/65	0/27	0/42	3
Aug. 5	0/67	2/127	5/130	0/67	0/63	7

* The numerator gives the number of affected turnips: the denominator, the number examined.

Stated briefly, the most brown heart came from the second and sixth seedings. First and third seedings were next in order while four and five were practically free from brown heart.

SOIL REACTION STUDIES

Hydrogen-ion concentration tests were made in connection with the field experiment on the effect of manure on brown heart. The field in question was marked off crosswise into ten zones in such a manner as to include a section of every row; thus 75 pH tests were made in each zone and the values correlated with the actual intensity of brown heart as determined by the examination of each turnip within that area. The results were recorded in Table 4.

From the foregoing tabulation it is obvious that the severity of brown heart does not appear to be correlated with soil reaction as expressed in pH values. Considering, however, only the actual field run of soil reaction test, it was observed that turnips from soil having the highest phH values were free from brown heart. Furthermore, such turnips were of a superior quality.

TABLE 4.—THE EFFECT OF SOIL REACTION ON BROWN HEART

Zone number	Total number turnips in zone	Total number brown heart turnips	Per cent brown heart	Average pH value
1	207	55	26.57	7.080
2	261	110	42.14	6.885
3	243	156	62.20	7.168
4	192	66	34.37	7.136
5	159	9	5.66	7.020
6	142	8	5.63	7.032
7	265	20	7.55	7.010
8	382	29	7.59	6.742
9	449	44	9.80	6.621
10	308	54	17.55	6.775

SUMMARY

Turnip brown heart, a physiological disorder, has been under investigation since 1928 when it was found to be responsible for annual losses in Prince Edward Island amounting to not less than $50,000. The name brown heart has been established through usage in the rural communities although it has been appropriately referred to in America and Europe as black heart, water core, water heart, punky core and woody centre. Typical symptoms are found in turnips ranging in size from seedlings to large roots, the only known method of detecting its presence being to cut into the turnip. It does not increase in storage, neither does it cause a rot although badly affected specimens become noticeably lighter in weight when stored for several weeks. Brown heart is recognized as a clearly defined brownish and mottled central area further characterized in freshly cut turnips by a glassiness and water-soaked appearance with concentric light and dark rings. Turnips thus affected have a decidedly bitter taste and when cooked are found to be distinctly woody. Brown heart has been found in Europe as well as in the United States and Canada. It is widely distributed in Prince Edward Island, but does not occur to any extent along the north side of the Island. Varietal tendencies have been noted and four different strains were found to be immune in 1932. With increased manure applications the disease decreased; and it failed to develop on the former sites of manure heaps. No significant difference has been determined experimentally with respect to seeding dates nor does the presence or absence of the disease appear to be critically correlated with soil reaction.

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RESUME

OBSERVATIONS SUR LE CŒUR BRUN DES NAVETS. R. R. Hurst, Laboratoire fédéral de pathologie végétale, Charlottetown, I.P.-E.

Le cœur brun des navets, une maladie physiologique, est l'objet de recherches depuis 1928; on a constaté qu'il cause tous les ans dans l'Ile du Prince-Edouard des pertes qui se montent à plus de $50,000. Le nom "Cœur brun" a été établi par l'usage dans les groupements ruraux, mais en Amérique et en Europe la maladie est connue sous d'autres noms et qui paraissent également appropriés, tels que cœur noir, cœur aqueux, cœur d'eau, cœur pourri et cœur liégeux. On a trouvé des symptômes typiques dans les navets, dans toutes les phases de la végétation, depuis la phase de la plantule jusqu'à la racine entièrement développée. Le seul moyen de découvrir la maladie est d'entailler les navets. La maladie n'augmente pas en cave; elle ne cause pas non plus de pourriture, mais les navets très affectés perdent beaucoup de poids au bout de plusieurs semaines de conservation. Dans le cœur brun la partie centrale du navet est brunâtre et tachetée. Les navets fraîchement coupés ont aussi une apparence imprégnée d'eau, et exhibent des cercles concentriques clairs et foncés. Les navets ainsi affectés ont un goût très amer et quand on les fait cuire ils sont tout à fait liégeux. Le cœur brun a été constaté en Europe ainsi qu'aux Etats-Unis et au Canada. Il est très répandu dans l'Ile du Prince-Edouard mais beaucoup moins sur la côte nord de l'Ile qu'ailleurs. Les variétés y sont plus ou moins sujettes. Quatre espèces différentes se sont montrées réfractaires en 1932. Lorsque la quantité de fumier était augmentée, la maladie diminuait, et la maladie ne s'est pas développée sur les emplacements d'anciens tas de fumier. Aucune différence significative n'a été déterminée expérimentalement en ce qui concerne les dates de semailles, et il ne paraît y avoir aucune relation entre la réaction du sol et la présence ou l'absence de la maladie.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM DATA COMPILED IN THE DOMINION BUREAU OF STATISTICS

Wholesale prices in Canada advanced in June, the index rising from 71.1 in May to 72.1. A rather substantial gain was registered in the vegetable products group in which the index rose from 65.2 to 67.4. In the animals and their products group the index advanced from 65.5 to 66.6, a gain of a little more than a point. Similarly fibres, textiles and textile products rose from 73.7 to 74.7. Gains or losses in the other sub-indexes were not large.

Retail Prices.—The total index number of retail prices, rents, and costs of services declined from 78.7 in May to 78.4 in June. The food index fell off a full point whereas the clothing index rose from 69.9 to 70.1. Fuel prices were slightly lower.

Physical Volume of Business.—The index of the physical volume of business dropped to 95.8 in June. It will be recalled that there was a sharp rise in this index in May when it advanced to 99.6, seven points above that for April, and almost equal to the level of production in the base year 1926.

The index of industrial production declined to 95.2. Mineral production fell from 146.3 to 127. The index of manufacturing fell from 100.2 in May to 88.9 in June. The index of food production rose from 85.1 to 88.9. There was a substantial increase in output of sugar, and increased exports of cheese and canned salmon, whereas flour production remained at about the same level as in May. Among other sub-indexes production of boots and shoes was higher and imports of wool and rubber advanced but cotton imports were lower. Tobacco released for manufacturing was larger in amount than in the preceding month. Exports of planks and boards advanced. Automobile, newsprint, electric power, and steel production declined. Car loadings were slightly under those in May. Construction continued at a low level. In this connection it may be worth noting that the index of the cost of construction was 84.1 in May and has varied only about three points during the past twelve months.

Agricultural Products.—Wholesale prices of Canadian farm products advanced from 56.9 in May to 59.3 in June. The index of field products advanced from 51.1 to 55.5 but that of animal products receded from 66.5 to 65.6. The total index was largely influenced by higher prices for wheat and coarse grains which overshadowed the lower prices paid for all livestock except hogs. Prices of eggs were somewhat stronger and prices of butter advanced slightly. In the case of wool, lower values were realized. Dry weather has affected crops, dairy and livestock production in many areas with consequent restriction of supply and strengthening of prices in grains and dairy produce whereas in the case of livestock, except hogs, the result recently has been heavier shipments and lower prices. In this connection the livestock market report published by the Livestock Branch shows that for the 29 weeks ended July 19th, sales of cattle at public yards were 327,926 head in 1934 as compared with 288,214 in the same period of 1933. In the case of calves sales in 1934 have been 205,390 head as against 176,752 in 1933. Sales of sheep have been lower, amounting to 135,437 in the first 29 weeks of 1934 compared with 142,049 head in corresponding weeks of 1933. Total hog gradings in the same period were 1,761,972 and 1,828,006 respectively. The index of agricultural marketings was 97.2 in June as compared with 130.6 in May. Grain marketings were 99.6 as against 140.1 in May. Marketings of wheat were lower but shipments of coarse grains were higher than in the previous month. The index of livestock marketings was 86.7 as compared with 87.8 in May.

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.9	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1933									
Jan.	63.9	43.6	35.1	57.9	79.1	68.1	62.2	56.1	112.0
Feb.	63.6	43.0	36.0	54.7	78.4	67.0	60.0	76.5	127.6
Mar.	64.4	44.7	38.0	56.0	77.8	68.4	62.5	129.0	135.8
April	65.4	46.8	41.1	56.4	78.0	69.8	65.1	104.1	112.7
May	66.9	51.2	46.9	58.4	77.0	76.4	72.7	95.4	110.4
June	67.6	52.6	49.4	57.9	77.0	82.2	79.8	221.9	119.9
July	70.5	60.1	60.8	59.0	77.2	84.1	82.6	221.9	119.9
Aug.	69.4	57.0	54.9	60.5	78.6	89.8	89.5	197.2	114.2
Sept.	68.9	54.7	49.5	63.4	78.8	90.8	90.2	101.1	115.7
Oct.	67.9	51.4	44.6	62.8	77.9	88.2	87.4	70.5	112.7
Nov.	68.7	53.8	46.7	65.8	78.1	85.5	83.9	41.8	111.1
Dec.	69.0	53.3	45.3	66.6	78.4	86.2	85.1	30.7	107.6
1934									
Jan.	70.6	55.3	47.9	67.8	78.7	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	79.2	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	80.2	93.1	92.0	63.8	97.0
Apr.	71.1	55.4	48.7	66.6	79.6	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.7	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.4	95.8	95.2	97.2	116.3

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1931, p. 15.

2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1931, p. 33, and Monthly Mimeographs 1933 and 1934.

3. Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products.

5. Including foods, rents, fuel, clothing and sundries, See Prices and Price Indexes 1913-1928, pp. 181-185, 290-293. 1926=100.

Prices and Price Indexes 1913-1931, p. 122, and Monthly Mimeo aphs 1933-1934.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

The index of cold storage holdings rose from 102.6 to 116.3 in June and continued its rise in July when the index was 126.1. Holdings of eggs were higher. Butter stocks were above those in June but not as large as is normally the case. Supplies of cheese showed little change while those of pork, lard and veal declined.

While indexes of production are lower than in the previous month, prices have advanced slightly and the situation would seem to be somewhat better than might have been anticipated at this season of the year.

Farm Prices in United States.—The index of prices paid to farmers for farm products in United States was 77 as compared with 74 in May. This index is based upon the 5-year average 1909-1914. The ratio of prices received by farmers to those paid for goods purchased was 63 in June and 61 in May, in June, 1933, it was 62. Comparable indexes have not been constructed for Canadian farm products.

Prices in Great Britain.—The monthly index number of prices of agricultural produce (corresponding months 1911–13 = 100) was 111 in April and 112 in May. Indexes of individual commodities in May were as follows: wheat, 59; barley, 98; fat cattle, 150; bacon pigs, 150; milk, 162; butter, 85; cheese, 123; wool, 89; poultry, 129; potatoes, 90. It is interesting to note that, according to the Journal of Agriculture "Wheat, at 4s. 8d. per cwt., was 4 d. dearer during May, and the index rose 2 points to 59. If allowance is made for the "deficiency payment" under the Wheat Act, 1932, the index would be increased to approximately 126, the effect of which would be to raise the general index for agricultural produce from 112 to 117. The average for barley further decreased by 5d. to 7s. 6d. per cwt., and the index by 5 points to 98. The index for oats also declined from 84 to 81 but, in this instance, the reduction was due to an increase which occurred in the base period, the average for May, 1934, at 6s. per cwt. being 1d. above that for April."

LA SITUATION ÉCONOMIQUE

PRÉPARÉ PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE, MINISTÈRE DE L'AGRICULTURE OTTAWA, PRINCIPALEMENT AVEC LES DONNÉES COMPILÉES AU BUREAU FÉDÉRAL DE LA STATISTIQUE

Une hausse des prix du gros au Canada s'est produite en juin; l'indice qui était à 71.1 en mai est monté à 72.1. Une hausse assez considérable a été enregistrée dans les cours des produits végétaux, l'indice passant de 65.2 à 67.4. Dans le groupe des animaux et de leurs produits, l'indice a passé de 65.5 à 66.6, une augmentation d'un peu plus d'un point. De même, les produits textiles se sont élevés de 73.7 à 74.7. Les gains ou les pertes dans les autres sous-indices n'ont pas été aussi considérables.

Prix de détail.—Le chiffre-indice des prix de détail, des loyers et des frais de services, qui était à 78.7 en mai est tombé à 78.4 en juin. L'indice des aliments a baissé d'un point entier tandis que l'indice des vêtements s'élevait de 69.9 à 70.1. Les prix du combustible ont légèrement baissé.

Volume physique des affaires.—L'indice du volume physique des affaires est descendu à 95.8 en juin. On se rappelle que cet indice était monté brusquement en mai, atteignant jusqu'à 99.6, sept points de plus que celui d'avril, et qui était presque égal au niveau de production de l'année de base, 1926.

L'indice de la production industrielle est tombé à 95.2; la production minérale qui était de 146.3 est descendue à 127. L'indice de l'industrie manufacturière qui était à 100.2 en mai est tombé à 88.9 en juin, tandis que l'indice de la production des aliments passait de 85.1 à 88.9. Il y a eu une augmentation considérable dans la production de sucre; les exportations de fromage et de saumon en conserves ont augmenté tandis que la production de la farine restait à peu près au même niveau qu'en mai. Parmi les autres sous-indices, la production de chaussures et de souliers était plus élevée, les importations de laine et de caoutchouc ont augmenté tandis que celles de coton diminuaient. Il s'est envoyé aux manufactures une quantité de tabac plus considérable que le mois précédent. L'exportation de madriers et de planches a augmenté. La production d'automobiles, de papier à journal, d'énergie électrique et d'acier a baissé. Les chargements de wagon étaient légèrement inférieurs à ceux de mai. La construction est restée à un faible niveau. Il est à noter sous ce rapport que l'indice des prix de revient était 84.1 en mai et qu'il n'a varié que de trois points en ces douze derniers mois.

Produits agricoles.—Les prix du gros des produits agricoles canadiens qui étaient à 56.9 en mai ont passé à 59.3 en juin. L'indice des produits des champs est passé de 51.1 à 55.5 mais celui des produits animaux descendait de 66.5 à 65.6. L'indice total a été largement influencé par les hauts prix payés pour le blé et les autres grains, laissant dans l'ombre les prix inférieurs payés pour tous les bestiaux à l'exception des porcs. Les prix des œufs ont un peu remonté de même que les prix du beurre. Quant à la laine, la valeur a diminué. Dans beaucoup de districts la sécheresse a affecté les récoltes, la production laitière et l'élevage, si bien que les approvisionnements ont diminué et que les prix ont remonté en ce qui concerne les grains et les produits laitiers; pour ce qui est des bestiaux, à l'exception des porcs, les expéditions ont augmenté, accompagnées d'une baisse de prix. A ce sujet, le rapport du commerce des bestiaux, publié par la Division de l'Industrie Animale, fait voir que pendant les 29 semaines finissant le 19 juillet, il s'est vendu aux parcs à bestiaux 327,926 animaux en 1934 contre 288,214 pendant la même période en 1933. En ce qui concerne les veaux, les ventes ont été de 205,390 têtes en 1934 contre 176,752 en 1933. Les ventes de moutons ont été plus faibles, se montant à 135,437 pendant les premières 29 semaines de 1934 contre 142,049 têtes pendant les semaines correspondantes de 1933.

Le classement total des porcs pendant la même période a été de 1,761,972 et 1,828,006 respectivement. L'indice des ventes agricoles a été de 97.2 en juin contre 130.6 en mai. Les ventes de grain ont été de 99.6 contre 140.1 en mai. Les ventes de blé ont diminué mais les expéditions d'autres grains ont été plus fortes que le mois précédent. L'indice des ventes de bestiaux était de 86.7 contre 87.8 en mai.

L'indice des produits conservés au froid s'est élevé de 102.6 à 116.3 en juin et a continué sa marche ascentionnelle en juillet pour atteindre le chiffre de 126.1. La quantité d'œufs conservés était plus forte. Les stocks de beurre étaient supérieurs à ceux de juin mais pas aussi considérables que la normale. Les stocks de fromage n'ont que peu changé tandis que ceux de lard, de saindoux et de veau ont diminué.

Les indices de production sont plus faibles que le mois précédent mais les prix ont légèrement monté et la situation paraît être un peu meilleure qu'il n'était à prévoir à cette saison de l'année.

Prix des produits agricoles aux Etats-Unis.—L'indice des prix payés aux cultivateurs pour les produits agricoles aux Etats-Unis était de 77 contre 74 en mai. Cet indice est basé sur la moyenne de 5 ans 1909-1914. Le rapport entre les prix reçus par les cultivateurs et les prix payés pour les marchandises achetées était de 63 en juin et 61 en mai; en juin 1933 il était de 62. Il n'a pas été préparé d'indices comparables pour les produits de ferme canadiens.

Prix en Grande-Bretagne.—Le chiffre-indice mensuel des prix des produits agricoles (mois correspondants 1911-13 = 100) était de 111 en avril et de 112 en mai. En mai les indices des différents produits étaient les suivants:—blé, 59; orge, 98; bœufs gras. 150; porcs à bacon, 150; lait, 162; beurre, 85; fromage, 123; laine, 89; volailles, 129; pommes de terre, 90. Une constatation intéressante, relevée dans le Journal of Agriculture, "c'est que le blé à 4s. 8d. le quintal, était de 4d. plus cher en mai et l'indice s'est élevé de 2 points à 59. Si l'on tient compte du paiement du déficit autorisé par la loi du blé 1932, l'indice serait porté à environ 126, ce qui aurait pour effet de faire monter l'indice général des produits agricoles de 112 à 117. La moyenne pour l'orge a encore diminué, de 5d. à 7s. 6d. le quintal et l'indice de 5 points à 98. L'indice pour l'avoine a baissé également de 84 à 81, mais dans ce cas la réduction est due à l'augmentation qui s'est produite dans la période de base, la moyenne pour mai 1934 à 6s. le quintal étant de 1d. supérieure à celle d'avril."

CURRENT PUBLICATIONS

RASMUSSEN, M.P. Some Facts Concerning the Marketing of Eastern Grapes, Part 1. Competition, Distribution, and Wholesale Marketing, Part II. Retail Distribution and Consumer Demand. Cornell Extension Bulletins 275 and 276; New York State College of Agriculture, Ithaca, N.Y.

The purpose of these two bulletins was to obtain all information possible on the marketing of Eastern grapes in order to provide a basis upon which Eastern grape producers might make plans for the future constructive development of the industry.

It was found that the principal fresh fruits which compete seasonally with grapes are apples, oranges, grapefruit, pears, peaches and bananas. California grapes are available for approximately seven months of the year while eastern grapes from any producing area have an extremely short season. This is a serious disadvantage in merchandising, since consumers are often uninformed concerning the actual length of the eastern grape season. Relatively high freight rates (considering distance hauled) probably restrict the distribution of eastern grapes compared with the California or vinefera type. The establishment of "commodity rates" and greater use of motor truck transportation might increase the area of distribution.

Part II comprises the results of a study of retail distribution of, and consumer demand for eastern grapes in five cities. In each city areas were selected that would be representative of the total city population, nationality of population, and the income group dominant in each area. The conclusions arrived at after studying retail outlets and interviewing consumers were as follows: Under normal circumstances, it is improbable that price acts as a deterrent to sales to any appreciable extent, since the quantity of eastern grapes usually purchased at one time is relatively small, namely, from 3 to 6 pounds, and purchases of eastern grapes for jelly or juice were generally largest in families with low incomes. The most serious criticism of eastern grapes was that they were "slack packed." If the demand for eastern grapes is to be increased, it seems desirable that steps be taken to insure full weight and pack. If table demand is to be increased, probably the grade and pack of grapes in small packages will have to be standardized to a greater degree than at present. This can probably be accomplished through central packing houses.

It is suggested that an educational campaign be conducted to acquaint the public of the health value of grape juice and the methods of making grape jelly. Attractive window displays and intensive advertising directed at the housewife should do much to stimulate demand for this product.

Recent developments in food merchandising lead consumers to expect to purchase all food supplies in one food store, which is frequently a combination grocery, fruit, vegetable and meat store. Joint efforts on the part of grape-growers' associations to induce a more active and sympathetic interest in the sale of eastern grapes on the part of chain and independent grocers might result in a considerable increase in demand for such grapes.

SHOEMAKER, J. S. Small-Fruit Culture. Blakiston's Son & Co., Philadelphia, 1934. Price $3.50.

This treatise on small-fruit culture covers the field in a comprehensive manner, but no attempt is made to deal exhaustively with these fruits and in a book of this size-four hundred odd pages—it would be out of the question. The author does, however, bring together a great deal of material that is of decided value to the student, the teacher and practical fruit grower. The following quotation from the author's preface sums up the main content of the book: "Much helpful information on small-fruit culture, the result of experiments, research and experience under a variety of practical conditions, is presented herein. This material has not yet been used to the

extent it deserves, largely because it has never been brought together in conveniently usable form. The discussion in the text is based on information derived from: the extensive but scattered literature; suggestions (hitherto unpublished) from specialists at various institutions; growers' experiences; and, the author's own work with small fruits."

The book is divided into six parts dealing respectively with the Grape, Strawberry, Bramble Fruits, Currant and Gooseberry, Blueberry and Cranberry. Each part is complete in itself and follows the same general plan, main topics being: The Industry, Regions and Districts; Development and Characteristics of Varieties; Cultural Details including Propagation, Location and Site, Planting, Tillage, Fertilizers, Irrigation, etc.; Fruit Bud Formation; Harvesting and Marketing; Insect Pests and Diseases.

The bibliography of three hundred and eighty-nine references is probably one of the best on small fruits. The whole book is in keeping with the more modern type of text books on fruit growing.—W. J. Strong.

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